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Mr. Geo. R. Smith, M.L.A., General Manager, Bell's Asbestos Co., Thetford Mines, Que., President, Canadian Mining Institute, 1905-6.

ANNUAL MEETING, 1906.

PROCEEDINGS OF THE 8TH ANNUAL GENERAL MEETING, HELD IN QUEBEC, ON THE 7TH, 8TH AND 9TH OF MARCH, 1906.

The Eighth Annual General Meeting of the Canadian Mining Institute was held at the Chateau Frontenac Hotel, Quebec, on March 7th, 8th and 9th, 1906.

1ST SESSION—WEDNESDAY MORNING.

The meeting was called to order at 10 a.m.; the President, Mr. G. R. Smith, in the chair. The Secretary, Mr. H. Mortimer-Lamb was unable by reason of illness to be present.

The President announced that for some weeks prior to the meeting the secretarial work had been most efficiently carried on by Dr. J. Bonsall Porter, Acting Secretary, who had very generously placed his services at the disposal of the Institute at a critical time. refusing all proposals of remuneration. On motion a very hearty vote of thanks was unanimously tendered Dr. Porter for the valuable work he had done.

The following members and guests signed the register of attendance:—

Geo. R. Smith, Bell's Asbestos Co., Thetford Mines, Que.
Eugene Coste, Mining Engineer, Toronto, Ont.
R. T. Hopper, Pres. Standard Asbestos Co., Montreal.
Major R. G. Leckie, Sudbury, Ont.
N. D. Daru, Surat, India.
Frederick Hobart, *Engineering and Mining Journal*, New York.
Frank D. Adams, D. Sc., Logan Prof. of Geology, McGill University, Montreal
E. D. Ingall, Geological Survey, Ottawa, Ont.
A. P. Low, Geological Survey, Ottawa, Ont.
Alfred E. Barlow, D. Sc., Geological Survey, Ottawa, Ont.
A. M. Campbell, Ottawa, Ont.
J. Obalski, Superintendent of Mines, Quebec, Que.
John E. Hardman, S.B., M.E., Montreal.
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W. H. Edwards, Black Lake, Que.
R. W. Brock, Prof. School of Mining, Kingston, Ont.
W. T. Rodden, Standard Explosives Ltd., Montreal, Que.
H. J. Williams, M.E., Manager Asbestos and Asbestic Co., Danville, Que.
J. A. Dresser, M.A., Montreal, Que.
A. McMelkin, McGill University, Montreal.
E. E. Winter, McGill University, Montreal.
L. Heber Cole, McGill University, Montreal.

PRESIDENTIAL ADDRESS.

The President addressed the members present as follows:

"Gentlemen,—It is with more than ordinary pleasure that I rise to perform the very agreeable duty of opening the 8th Annual Convention of the Canadian Mining Institute, and of welcoming you to the ancient and hospitable city of Quebec, the cradle of the Canadian nationality.

"We meet to-day on historic ground. This very spot, the site of this magnificent hotel, was for many generations the seat of Government of New France, and here was founded her colonial Empire. Immediately below the far-famed terrace surrounding us on every side we can look down upon the narrow strip of land hemmed in between the river and the rock, and here it was, that Champlain's builders erected the first European edifice in New France. The first Canadian sappers and miners, a few years later, began their work upon almost the identical spot whereon the miners of to-day, are assembled to discuss the progress and the prospects of Canada's mineral development.

"Here, was laid the foundation of that French Sovereignty, which from the old Chateau St. Louis was exercised over the enormous territory extending from the mouth of the Mississippi River to the Great Canadian Lakes and thence along their shores and those of the St. Lawrence River and Gulf to where the waves of the Atlantic lap the eastern shore of the Western World.

"Assembled, as we are, under the very shadow of the splendid monument erected to the memory of the first Canadian Governor and founder of Quebec, within the walls of a modern chateau where we can still hear the ghostly echoes of that bold defiance that the haughty old Count Frontenac hurled at his country's foes, it would be strange indeed, if our thoughts did not run back at times to the very beginning of things in the history of this rapidly developing Canada of ours. We are even tempted by the well-known peculiarities of stratification in the rocks of the famous 'Quebec Group' to seek to penetrate the veil which separates the earliest chronicles of the country from pre-historic times and to hark back to the glacial period of our planet's existence. Even when the fiat went forth which first shed created light upon

a world of chaos the Laurentian hills, those rocks upon which Quebec is built, lifted aloft their hoary heads white with the snow of a thousand years.

"Not many generations passed away after Champlain's founding of Quebec, before successful efforts were made by the pioneers of New France to wrest from the vitals of the earth the hidden wealth underlying, so contemptuously referred to at a later date by some of the attaches of the French Court.

"The distinguished French statesman, Colbert, who, like his royal master, Louis XV, was deeply interested in the progress and prosperity of New France, recognized not only the vast importance of retaining the fur trade of America in the hands of the French, but realized still more, the desirability of the proper cultivation of the soil and the operation of mines. Less than three-score years after the founding of Quebec, M. de la Tessiere, a French engineer, who had been instructed by Colbert to explore the North bank of the lower St. Lawrence, discovered, in 1666, the iron deposits of Baie St. Paul. The Intendant Talon was instructed by the Minister to carry on similar explorations in other parts of the country. It was under his auspices that the mineral wealth of the St. Maurice country, in the district where the Radnor forges were subsequently erected, was first brought to light.

"The French engineer, M. de la Potardiere, who was sent to Canada to inspect and report on these mines, failed to justly estimate the value and importance of the deposits in question, and of which we find early mention in the diary of the Ursulines of Three Rivers, and so their development was for some time delayed. Frontenac, however, in 1672, refers to them as of considerable importance. In this view he was corroborated by De Denonville in 1681.

"The first Company to develop these mines was formed in 1733. Though it was not until some time later that they were placed in really successful operation.

"The St. Maurice forges were, nevertheless, the first of their kind in America and in 1739 they were described as an honour to Canada. The famous Swedish naturalist, Paul Kalm, who visited this country in 1749, spoke of them as quite as well equipped as those of his own country, and they found plenty of employ-

ment in smelting the ore and casting the product into stoves to heat the dwellings of the early Canadian settlers.

"It is neither necessary, nor is it within my province as President of the present Convention, to invite you, who are all so well acquainted with the subject, to a retrospect of that period of mining development, during which our knowledge advanced by mighty strides, from those days to which I have just referred up to the present era, in which new operations have attained gigantic proportions in so many districts of the Dominion, and in which we are in sight of still more astounding developments.

"There is no doubt that we have entered upon a period of remarkable discoveries as well as of wonderful mining development. The Cobalt deposits and those of the Lake Chibougamoo District are among the latest to claim public attention.

"It is hardly necessary for me to speak of the present and continuing development of our asbestos and chrome iron industries, as these will be described to you in detail in papers which will be read before this Convention.

"The enormous development in transportation facilities in districts, hitherto inaccessible, which will result from the construction of the Grand Trunk Pacific and other contemplated roads, must necessarily lead to further commercially valuable discoveries. There is also a constant and increasing demand for mining locations and I believe that I am well within the mark in saying that the revenue of the Mining Department of the Province of Quebec, will show for the current year an increase over that of last year of more than 500 per cent.

"The energetic efforts of the present Minister of Mines for this Province, the Hon. John Prevost, to assist as much as possible in the development of the Province, are well known to all of us who reside within it, and I feel that he will not only receive with interest our suggestions, but will endeavour to carry out the wishes of the mining men and the public in general in the development of this industry.

"I take this opportunity in conclusion of thanking the members for their kindness in electing me again by acclamation, and I trust that nothing will occur during the coming year to make them feel that their confidence in me was misplaced."

The Report of the Council for the past year was then presented as follows:—

REPORT OF THE COUNCIL FOR 1905-6.

The Council takes pleasure in submitting the following Annual Report for the Members of the Institute, required by Paragraph 34 of the By-Laws of the Institute.

MEMBERSHIP.

The following table shows the membership of the Institute arranged by Provinces and other countries for the past year as compared with the preceding six years.

COMPARATIVE STATEMENT SHOWING DISTRIBUTION OF MEMBERSHIP

AS AT 31ST DECEMBER, 1898-9-1900-1-2-3-4-5.

	1898	1899	1900	1901	1902	1903	1904	1905
Nova Scotia	16	16	19	27	31	30	24	22
New Brunswick	2	1	2	2	1	1	1	1
Quebec	66	77	77	77	79	69	68	73
Ontario	44	66	91	83	107	108	103	130
British Columbia	42	65	72	67	72	68	55	55
Manitoba	..	..	..	..	2	2	1	2
Newfoundland	..	1	2	2	2	2	1	2
Alberta	5	5	5	6	6	7	10	11
Yukon	..	..	..	2	5	11	9	9
Great Britain	4	9	7	12	14	12	14	12
United States	11	17	26	30	36	36	36	42
Other Countries	..	3	8	11	6	11	11	11
Students	2	15	14	12	92	78	8	8
Affiliated students	..	..	..	..	..	..	83	83
	192	227	323	331	453	435	424	461
Died during the year	2	4	4	4	2	3	3	2

It will be seen that there is a slight increase in membership over that shown last year.

DECEASED MEMBERS.

The Council records with profound sorrow the death of Mr. W. Dickson Craig of the Canada Iron Furnace Co., Midland, Ont., and also that of Mr. Alex. Macdonald of St. John's, Que.

SECRETARY'S OFFICE, LIBRARY AND READING ROOMS.

At the last Annual Meeting, Mr. H. Mortimer-Lamb of the *Mining Record*, Victoria, B.C., was appointed Secretary of the Institute.

The Council after careful consideration of the proper location of the Secretary's Office entered into an arrangement with the Canadian Society of Civil Engineers, whereby the use of their commodious quarters at 413 Dorchester St., W. Montreal, were shared by the Institute. By this arrangement a special room was secured for the use of the Secretary of the Institute, in which the Institute's library was placed.

Members of the Institute are also given the free use of the Library and Reading rooms of the Society of Civil Engineers, and also of a large Lecture Hall in the same building.

This arrangement has proved very satisfactory and the attention of Members of the Institute visiting Montreal is called to these new quarters and to the comfortably equipped and well furnished Reading Room which they contain. These rooms are open from 9 a.m. until 10 p.m. except on Sundays and public holidays,and during a brief period in the summer.

MEETINGS.

The Annual General Meeting was held in the City of Montreal on the 1st, 2nd and 3rd March, 1905, and was one of the largest and most successful meetings that have been held by the Institute.

Five meetings of Council were held during the year at headquarters.

PUBLICATIONS.

Thirty-three Papers were read and discussed at the Montreal Meeting, and these, with the detailed proceedings of the meeting,

now form Volume VIII of the Journal of the Institute, which has just been issued to members in good standing.

STUDENTS COMPETITION AND AWARD.

Several Papers were submitted by student members at the Montreal Annual Meeting, 1905. After receiving the reports of the Committee of Judges, the Council awarded the President's Medal to Mr. L. Heber Cole of McGill University, Montreal, for his paper entitled "Mine Surveying as carried on at the Centre Star Mine, Rossland, B.C."

The Council also awarded 3 cash prizes of $25 each as follows: in Mining, to Mr. L. Heber Cole for his paper above referred to; in Metallurgy, &c., to Mr. A. McL. Hamilton, McGill University, Montreal, for his paper entitled "Notes on Reverberatory Furnace Smelting at Anaconda," and to Mr. Geo. S. Hanes, School of Practical Science, Toronto, for his paper on the "Solubility of Cobalt-Nickel Ores in Ammonia."

The President's Medal will formally be presented to Mr. Cole at the coming Annual Meeting.

The Council takes pleasure in congratulating the above gentlemen on the very creditable papers they have presented to the Institute.

Following the practice inaugurated last year, the Secretary this year printed 1,000 copies, or to be quite accurate, 1025 copies of Volume VIII, and in addition he printed 500 copies in separate form of every paper submitted in advance. This preliminary pamphlet edition was issued early in the year, thus giving opportunity to all the members to discuss the papers in advance of their final issue.

Submitted on behalf of the Council.

GEO. R. SMITH,
President.

J. BONSALL PORTER,
Acting Secretary.

TREASURER'S REPORT.

Mr. J. Stevenson Brown, Treasurer, presented the Financial Statement for the year, duly audited and approved by the Council, as follows:—

TREASURER'S STATEMENT.

YEAR ENDING FEBRUARY 1st, 1906.

RECEIPTS.

Balance from last year		$ 1900.95
SUBSCRIPTIONS—		
253 Ordinary Members at $10.00	$ 2530.00	
6 Student Members at $2.00	12.00	
38 University Members at $1.00	38.00	
Arrears collected	252.00	
		$ 2832.00
Sale of Publications		14.50
Sale of Safe		50.00
Dominion Government Grant		3000.00
Loan		250.00
Interest		40.05
		$ 8087.50
LESS		
Disbursements per Statement		6895.66
Balance on hand		$ 1191.84

Audited and Certified Correct,

P. T. ROSS & SONS,
Chartered Accountants.

MONTREAL, Feb. 13th, 1906.

SUMMARY STATEMENT.

SHOWING DISTRIBUTION OF DISBURSEMENTS TO THE VARIOUS WORKS AND BUSINESS OF THE INSTITUTE.

PUBLICATIONS—		
Transactions, Vol. VII (Bal)	$ 912.22	
Transactions, Vol. VIII	2260.36	
Postage and Express	121.94	
		$3294.52

LIBRARY—		
Rent including Bonus $100	$ 575.00	
Telephone	37.34	
Sundries	135.20	
		$ 747.54
MEETINGS—		
Annual Meeting	$ 173.15	
Reporting Meeting	95.45	
Nelson Meeting	35.00	
		$ 303.60
SECRETARY'S OFFICE—		
Secretary's Grant	$ 600.00	
Printing, Stationery, &c	318.09	
Postage and Telegrams	68.18	
Travelling Expenses	264.55	
Sundries	60.53	
		$1311.35
TREASURER'S OFFICE—		
Treasurer's Grant	$ 500.00	
Printing and Stationery	59.84	
Postage, Telegraphs, &c	86.51	
Bank Charges on cheques and drafts	62.80	
Sundries	24.50	
		$ 733.65
SUNDRIES—		
Advertising	$ 100.00	
Legal Expenses	70.00	
Prizes to Students	75.00	
Returned Subscription	10.00	
Loan Repaid	250.00	
		$ 505.00
		$6895.66

DETAILED STATEMENT OF AMOUNTS PAID IN 1905 BELONGING TO THE BUSINESS OF THE PREVIOUS YEAR.

Sundry Acts. per E. Coste	$ 27.30	
Postage on Circulars and Volume VII, E. Coste	29.96	
F. Cirkel, January Acct.	13.23	
Mail Job Printing Co.	13.50	
Bell Telephone	1.10	
Advertising to 31st Jan., 1905	37.50	
Stationery	11.46	
Printing	51.50	
Postage Volume VII, per E. Coste	48.00	
Postage, Express, &c. Vol. VII, F. Cirkel	24.06	
Printing List of Members	15.00	
Freight on Vol. VII.	7.60	
J. M. Clark, Services re By-laws	50.00	
Mail Job Printing, Balance due on Vol. VII	912.22	
		$1242.43

Balance 1st Feb., 1905	$1900.95	
Less Liabilities as above	1242.43	
		$ 658.52

P. S. ROSS & SONS,
Chartered Accountants.

In presenting the financial statement for the year, it is worthy of note that while the revenue from membership has increased by $81.00, the expenditure chargeable to the year's business has decreased to the extent of $2,003.08 as follows:—

Total expenditure chargeable to the year ending February 1st, 1905	$7,656.31
Total expenditure chargeable to the year ending February 1st, 1906	5,653.23
Decrease	$2,003.08

The amount of past due subscriptions collected during the year, justifies the policy of not dealing too hastily with members who may be in arrears.

In conclusion I beg to furnish you with a statement which will in some measure show the financial growth of the Institute during the six years I have had the honour to be Treasurer, namely, since March, 1900. The balance at the credit of the Institute at the close of each financial year was as follows:—

YEAR.			
1900			$ 484.87
1901			630.61
1902			957.40
1903			1,682.49
1904		$ 3,048.73	
	Less liabilities	1,139.15	$1,909.58
1905		$1,900.95	
	Less liabilities	1,242.43	$ 658.52
1906			$1,191.84

Respectfully submitted.

J. STEVENSON BROWN,
Treasurer.

After some discussion, wherein it was made clear that the Council had, by effecting the removal of the Library and Office of the Institute from 80 Stanley Street, Montreal, to rooms leased from the Canadian Society of Civil Engineers, at 413 Dorchester Street, Montreal, secured for the Institute far more commodious and more convenient quarters than those previously occupied, the Report of the Council and the Treasurer's Report were adopted.

NEW MEMBERS.

The following new members were elected during the year:—
O. Aubin, Sudbury, Ont.
W. McVittie, Sudbury, Ont.
R. R. Gamey, Sudbury, Ont.
J. R. Gordon, Sudbury, Ont.
The Hon. F. Cochrane, Sudbury, Ont.
J. J. Campbell, Nelson, B.C.
H. E. T. Haultain, Craigmont, Ont.
John Hopp, Stanley, B.C.
Tyndall Phipps, Princeton, B.C.
J. Taylor Simpson, C.E., Ottawa, Ont.
E. T. Corkill, Inspector of Mines, Toronto, Ont.
C. Fernau, Gen. Mgr. Canadian Metal Co., Nelson, B.C.
E. L. Hermann, Massey, Ont.
T. Kiddie, Crofton, B.C.
G. C. Tunstall, Montreal, Que.
W. J. Watson, Ladysmith, B.C.
Donald Ferguson, Goldfield, Nevada
J. Stanley Lecky, Montreal, Que.
F. B. Chapin, Toronto, Ont.
S. R. Clarke, Toronto, Ont.
T. Frank Richardson, Montreal, Que.
Walter T. Ross, Montreal, Que.
W. L. Hine, Toronto, Ont.
R. K. Russel, Pembroke, Ont.
G. D. Hardy, Toronto, Ont.
G. W. McNaughton, Sydenham, Ont.
H. J. Carnegie Williams, Bruce Mines, Que.
William Caldwell, Toronto, Ont.

Alex. Langwell, Cobalt, Ont.
A. J. McNab, Trail, B.C.
Robert A. Klock, Montreal, Que.
Charles McRae, Sudbury, Ont.
Daniel Ford, Montreal, Que.
J. K. Maclennan, Sudbury, Ont.
W. W. Stull, Sudbury, Ont.
E. H. Low, Sudbury, Ont.
Boyd A. C. Caldwell, Lanark, Ont.
J. F. B. Vandeleur, Toronto, Ont.
R. W. De Morest, Sudbury, Ont.
B. B. Harlan, Toronto, Ont.
A. W. Sparling, Toronto, Ont.

APPOINTMENT OF SCRUTINEERS.

On motion, Messrs. A. P. Low, F. Hobart, and J. J. Penhale, were appointed scrutineers of the ballots for the election of officers for the year 1906–7. The Scrutineers were specially instructed regarding the qualifications of voters and the recognition of ballots.

ELECTION OF AUDITORS.

It was moved, seconded and agreed to that the Auditors for the ensuing year be Messrs. P. S. Ross & Sons, of Montreal. An adjournment was then taken until 3 o'clock.

WEDNESDAY—AFTERNOON SESSION.

In the absence of the President, Mr. Eugene Coste took the Chair.

MINERAL STATISTICS.

Mr. E. DREW INGALLS, in charge of the Mineral Division of the Geological Survey of Canada, presented a statement in detail of mineral production in the Dominion for the past year. He stated that the value of this output was over sixty-eight million dollars, or an increase of eight and a half million over the 1906 returns.

Mr. W. G. MILLER, Provincial Geologist of Ontario, said that the mineral production of this Province during 1905 had been a

record one, the value of the products, in refined state, having been about $23,500,000. Mr. Miller stated, however, that the method employed in Ontario, in the compilation of mining statistics, was not to consider the refined values, but only the value of the product based on the price at which it is sold before being exported for refining; that is, of course in such cases where the refining is done abroad. Referring to Mr. Ingall's statement in respect to nickel output, Mr. Miller said:—

"Mr. Ingall has referred to the nickel output. This has been larger than it has ever been before, and this year there were produced 9,503 tons of nickel in the Sudbury District. There was an output of 4,525 tons of copper. As for the silver from Cobalt, Mr. Ingall has given figures for that. 2,441,000 ounces have been shipped, but at the end of the year a great deal of silver was in storage. There is no plant in America suitable for refining these ores, although processes are available. One plant is now started at Copper Cliff, another is being installed at Hamilton, and the Delora works in Hastings County will probably treat these ores. I think in refining these ores the method employed will be the same as used for years in Germany. We can adopt the methods that have been used with similar ores in Saxony and Bohemia. Our production of steel is also far above what it has ever been. There were 138,387 tons made; pig iron, 350,704 tons. Mr. Ingall has referred to the increase in the production of oil and gas in Canada generally. We have had a very large increase in Ontario. A couple of years ago a bounty was given for crude oil. This probably had some effect in stimulating that industry. Our gold production is not increasing. It is practically at a standstill. There was $100,000 worth of cobalt shipped from the Cobalt District outside of what was in storage. I estimate the total production of the Cobalt Camp during the last year at approximately $2,500,000. This includes what was in storage at the end of the year. Of course that production is not great compared with some mining camps, but when we consider the small number of men that produced that amount at Cobalt I think it is rather striking. I might say that in one mine of which I have a statement of costs for building, supplies, freight, workmen, etc. the total expenditure amounted to $50,000 and it has produced

$410,000 worth of ore. Most of the Cobalt properties are not worked very methodically. The claims are developed by open cuts, but only two or three mines are being systematically developed."

Mr. TYRRELL.—There is comparatively little to be said about recent mining development in the Yukon. The territory undoubtedly has had its extreme boom days. All the gravel of that country was exceedingly rich, or rather much of it, as you have all heard. I remember I was present one time when a single shovel full of gravel was taken out and as much as $625.00 worth of gold was panned therefrom in my presence. But while much of the very richest of the ground has been worked out, still there is a vast amount of gold left in the country. Conditions must, however, be made easier before these deposits can be worked on an important scale, but, ultimately, operations will prove very profitable. Transportation costs are at present excessive. Again a systematic arrangement must be made to bring in the necessary supply of water to wash the gravels in the country, and in some cases, in the bottom lands, large dredges will undoubtedly be very successful.

While the output last year fell off about $2,000,000 from the year previous, it was due in part to the great scarcity of water; probably almost as much as on account of the falling off in the value of the ground. A systematic development on a large scale has not been thoroughly undertaken. You can take my word for it that the country will yet produce a vast amount of gold; but much of it will possibly have to lie there for a few years until conditions of life become easier and transportation charges are lowered.

Mr. COSTE.—I might refer to one point which is brought out by the figures of production just given us, and which, I think, indicates that one of our mining enterprises is in need of amelioration. I refer to the iron ore question. We have just been shown by Mr. Ingall that the quantity of Canadian ores, which we use in Canada, in our rapidly developing furnaces and smelting works, is falling off, and that the proportion of iron ores from Canada used in these works is relatively very small. Most of our geologists who have studied the question are quite convinced that we have enormous iron ranges in Ontario and in other parts of the country

and I think we should do all we can towards utilizing these resources and developing our own iron mines. As you are aware the production of iron ore is of great importance to any country. It means business for railways, and a large employment of labour and capital generally. Hence the Institute may well consider the question of Government bounties on iron ores. As you all know bounties have been given for foreign ore and for iron from foreign ore by the Dominion Government, and a great many mining men have felt that that was not a good way to forward the development of our own mines. Some gentlemen, who will be here to-morrow, will bring to your notice a suggestion that in future Dominion Government bounties be granted on Canadian ores only, or possibly also on ores from British colonies, so as to include the ores from Newfoundland. Of course, we pay high duties on all Canadian ores we ship to the United States and it seems very strange therefore that we should give a bounty to American ores, that are smelted in this country and if we could effect a change in that policy we would greatly aid the development of our iron mines.

The following papers were then read and discussed:—

Rare Earths in the Pegmatite Veins of our Laurentian Range. By J. Obalski.

The Ore Deposits and Geology of the Sudbury District. By Hiram H. Hixon.

EVENING SESSION—WEDNESDAY.

The meeting re-convened at 8 p.m. the chair being occupied by Dr. Frank D. Adams, Vice-President, who announced that the President had made arrangements with the authorities for the Steamer *Montcalm* to be placed at the disposal of members on the following day, when an excursion would be made up the St. Lawrence in order that those participating might have an opportunity of viewing the ice-breaking steamer at work.

Mr. J. E. HARDMAN then delivered an interesting lecture, illustrated by lantern slides, on the Chibougamou Mining Region. Referring to the first discovery of mineral in this area, he said in part:—

THE CHIBOUGAMOU MINING REGION.

In order that there may be a better understanding of the region I am to talk about, I first wish to call your attention to the maps on the wall, by which I will show to you where this new Quebec mineral region is situated. You will note that it lies approximately along the 50th parallel of latitude and between the 74th and 75th meridians of west longitude, the portion colored red indicates the particular spot I have personally visited.

As Mr. Low will follow me with a much more scientific and accurate statement than I am able to make I will make my verbal description very briefly and rapidly.

Attention was first drawn to this Chibougamou region by the report of Mr. James Richardson dated 1871, who, in 1870, explored the section I have pointed out on the map. Later, in 1885, Mr. A. P. Low passed through this same region in his Mistassini expedition, and a year later also traversed it. The Geological Survey Reports for 1885 and 1892 contain Mr. Low's reports of what he saw.

As far back as the end of the 17th century, missionaries had been in this part of Northern Quebec, but their published descriptions contain no mention (of value) of the metalliferous resources. Prof. R. W. Brock, still later, in 1896 I believe, made a reconnaissance of some of the region west of Wahconichi Lake. These few reports, previous to 1893, contain all the knowledge of this region obtainable up to the time of Mr. Peter McKenzie's explorations in 1903 and 1904.

The Indian population of Northern Quebec is sparse, and widely scattered. On one side of this section the total number of Indians seen was but eleven, and during the greater part of the six weeks, there was no evidence of any animal life beyond the occasional rabbits seen. I have been told that, prior to the great fire of 1871 which swept over this country, game was plentiful, but the fire drove the large game, moose, caribou and bear, over the divide on to the waters of the St. Maurice and that, as yet, it has not returned.

In August, 1903, Mr. Peter McKenzie, of the McKenzie Trading Co., while visiting one of his posts on Chamouchouan Lake, conceived the idea of going to Chibougamou to see Mr.

Richardson's "Paint Mountain." Accompanied by two Indians who claimed to know the route Mr. McKenzie started off, only to find that his men did *not* know the way to Chibougamou, and to which place he had to find his way without a guide. While examining Paint Mountain and the shores in the vicinity, Mr. McKenzie found the large quartz deposit which had given him local fame, and also the island on which the very valuable veins of asbestos occur. He also noted the presence, in other places, of copper pyrites and the great variation of the compass in a contracted area which led him to the belief that large bodies of iron ore were in the vicinity. Since then it has been found that this great variation is due to the presence of magnetite disseminated through the rock of a hill called the "Magnetic Cone," but in too small a quantity to constitute a commercial ore of iron. In March of 1904 a second visit to the region was made, and additional samples obtained.

Upon Mr. McKenzie's return to Quebec in the spring of 1904 he made application to the Department of Mines for Licenses upon certain portions of this new territory. No official maps existing of this section, it is not unnatural that the story of the finds became a wonder story. In this way, amongst others, the attention of the then Premier, Mr. S. N. Parent, was attracted to the new region, and Mr. Obalski, the Inspector of Mines, was requested to accompany Mr. McKenzie on his return trip, which took place during August and September, 1904.

Mr. Obalski returned in October, having verified Mr. McKenzie's discoveries, and having also proved that the large cupriferous quartz deposit carried very respectable values in gold. Mr. Obalski's first public opinion was printed in the November issue of the *Canadian Mining Review*, and by this means the public were first notified of this rich new section in the northern part of Quebec.

I have had some lantern slides made from photographs taken by myself and by Mr. McKenzie during my inspection of the region in June of last year, and I will ask Mr. Robertson to be good enough to manipulate the lantern and show these pictures on the screen. They will give you a far better idea than my words can do of the character of this northern country, which at the present, is a real wilderness, some 200 miles distant from rail communication,

that is, from Roberval on the Lake St. John Railway. This 200 miles has to be traversed on foot or in canoe, and in that distance your goods will have to be portaged some 48 times, and for distances varying from 100 yards to nearly, or quite, two miles. With the pictures I am now to show to you, and from Mr. Low's paper I am sure you will obtain an approximately accurate idea of your new mineral territory.

(Mr. HARDMAN here gave a lantern illustration of the district.)

Mr. LOW:—After Mr. Hardman's description of the region I think I need say little about it in general. I will only take up your time for a few minutes pointing out our geological information on the Chibougamou region. The rocks of this region are almost entirely of an igneous origin. In the far north at Lake Mistassini, we have large areas of limestone which do not contain fossils, and which bear a very close resemblance to the limestone in the Animikie of Lake Superior. They rest upon a series of sheets of diabase, which are associated with beds of granite conglomerate, and small bodies of arkose. These bedded conglomerate and arkose rocks, resemble closely from what I can see, the rocks in the Temiskaming region and about Cobalt. Along the northern part of Lake Wakonichi is a cliff which gives a section of about 200 feet. These rocks, as you will see, continue down the east side of this lake, and are found again on the western side. They are cut off by an area of newer granite. The serpentine is found in two bands, one on the north side of Mackenzie Bay of Lake Chibougamou, and the other on the south side. The northern band has been traced from a short distance above the head of MacKenzie Bay to about a mile or so beyond its eastern end. After that it is covered with moss and vegetation, trees are very thick, and it is hard to prospect in any way thoroughly. The southern band starts from the narrows and runs four or five miles, being cut by Rapid River which runs into the Bay. There is still a third band on the hill called Cummings Mountain. The asbestos from there is of a better quality. These two bands of serpentine appear to be a more basic form of the diabase or belong to an older eruption of Keewatin age; they have been squeezed into narrow bands probably during the foliation of the rocks by the gabbro. That gabbro appears to be a mineralized agent of the diabase schists

along the contact. In this connection we find at Paint Mountain a large mass of quartz, and many small stringers of sulphides of copper, iron, while pyrrhotite has been found since I left there. To the south of the gabbro we come to an area of newer granite; this also extends southwest. Then we come south of it, to another area of the diabase rocks which lack conglomerate and appear to be very lean in minerals. At Obatogamon, that lake of the crooked channels, there is a still newer granite. It is remarkable that at the contacts between the green schists and this granite, there is little mineralization, and the quartz stringers are barren of gold. The place for the prospector I might say, would be on the serpentine bands, which contains the asbestos, and along the contacts between the green schists and gabbro. Wherever I saw the contact between these rocks, the green schists always carried more or less copper, and there is a fair probability that something stronger and richer will be found along that contact, or close to it. In the region of conglomerates associated with the diabase, the only thing that has been found was at Specular Point of Lake Wakonichi where the newer granite had fractured the rocks there, small veins of specular iron ore were found in abundance. The rocks bear such a close resemblance to those rocks at Cobalt that I think it is well worth while to prospect them. I do not know much about the conditions under which the Cobalt ores were formed, but I do not think we can cite any authority who does know, consequently not knowing these conditions, I think that valuable mineralization may happen here as well as in Cobalt, it would be well for the prospectors to pay close attention to the small veins that occur in these rocks.

The following papers were then read:—

Probabilité de trouver des Mines au Nord de la Province de Quebec. By J. Obalski.

Notes sur un Dépot de Pyrrhotine Nickelifere sur une pointe appellée, "Malachite Point. By A. Moscovici.

On the Advisability of the Establishment of a Federal Department of Mines. By H. Mortimer-Lamb.

A Canadian Department of Mines or Geological Survey. By J. B. Tyrrell.

FEDERAL DEPARTMENT OF MINES.

After the reading of the two papers last mentioned, the following discussion took place.

Major LECKIE:—I think it would be well for us to bring this discussion to some practical point, and I would suggest that the matter be laid before the Government as soon as possible, so that the Bureau of Mines may be thoroughly instructed in connection with the Geological Survey, or perhaps, under the direction of a responsible Minister, who should have a staff of the very best men in the country. We have in Canada many men of the highest technical accomplishments who are worthy of the confidence of the Government, and who ought to have salaries commensurate with their ability and with the time it has required them to acquire the information that they have. The members of the Geological Survey hitherto have been paid but a mere pittance, comparatively speaking, not even equal to that of a second class clerk, instead of having a salary equal to a Superior Court or King's Bench judge. I dare say I have been longer in the mining business than any man in Canada with the exception of my friend Dr. Douglas. I remember in 1861, when I first became interested in mining at Acton, Dr. Douglas was then toiling away at Harvey Hill, and the Geological Survey of that day was comparatively an unknown branch to the public, although abroad, at the Exhibition in Paris in 1859 it did more to make Canada known than anything else connected with the Government of Canada. The mining industry has grown from that time to rank with the very foremost industries of the whole country. Our mineral production now amounts to something between $60,000,000 and $70,000,000 and follows very closely upon the value of the agricultural products, The mining industry is quite as much entitled to the recoguition of the Government and the people generally as the agricultural industry. I have prepared a resolution to bring the matter before the Government, and we might take action thereon to-night. Of course, this resolution, which I propose to submit, may be subject to some amendment. I have drawn it up as follows: "That in view of the growing need on the part of our mining community for Government assistance in the development of

our mining industries, the President of the Mining Institute be requested to proceed to Ottawa accompanied by as strong a delegation as he can secure, in order to impress upon the Government the claims of the Mining Institute in Canada for assistance in the development of our mining industries, a claim for practical aid as set forth this evening in the paper to the Institute by its Secretary."

Mr. TYRRELL:—I have much pleasure in seconding that motion of Major Leckie, and I sincerely trust that some definite and decided action will be taken in the matter of bringing the mining interests of the country forcibly before the present Government. I think that the present would be a particularly favourable time. Parliament has just gone into session, and I have not the least doubt that the Government would listen to a delegation.

The President:—You have heard this motion by Major Leckie, seconded by Mr. Tyrrell. I might say that Mr. Lamb's idea was that it was of great importance to urge upon the Government the necessity of doing something at once. The Geological Survey has been dragging on now for five years, indifferently; Dr. Bell, as Mr. Lamb states, is doing the work and not receiving the proper recognition, the whole survey being allowed to drift during this time, when it is very important that it should be doing the best work that can be done for the mining industries of the Dominion. This committee, as Major Leckie proposes should go to Ottawa to endeavour to help on in a practical way mining in the Dominion, as the United States Geological Survey so efficiently aids the mining industries of the United States.

Dr. ADAMS:—I might say that this resolution which states that the President is requested to go to Ottawa with a delegation to press the claims of the mining industries for additional practical aid as set forth in Mr. Lamb's paper, does not necessarily bind the Institute to recommend the appointment of a Minister of Mines or the establishment of an independent Department of Mines, but merely to inform the Government of the present requirements of the mining industry, and to urge the necessity of action in this direction.

Major LECKIE:—Special reference is made in Mr. Lamb's paper to the desirability of popularising Government reports.

When Earl Grey made his statement recently, advising that the blue book should be read by the people, there was a difficulty in the way at once. I have stacks of blue books coming to me week after week and I have tried day after day to interpret these, and tried to put them before the people, and I defy any man to make anything out of them. They are most incoherent. What is the meaning of this? I maintain it is because there has not been proper provision made by the Government to properly deal with the questions.

To-day we hardly know what ores we have in Canada as a matter of practice. I certainly think that the resolution that has been moved to-night, if it will do nothing else than stir up the Government to give us literature that we can bring before the people, will do much good, and I for one, believe—I took the train within an hour's notice to come to Quebec, because I heard this matter was to be brought forward—that this meeting has now the opportunity of promoting a movement, which will be of great and permanent value to the mining industry of Canada.

The resolution was then put and carried and the meeting adjourned.

MORNING SESSION—THURSDAY.

The President, Mr. G. R. Smith in the Chair.

MINING LAWS.

The Acting Secretary, stated that he had been asked to recommend that the Institute appoint a committee to consider the possibility of bringing about a codification of the mining laws of the respective provinces. Dr. Porter added in this respect, that in his private correspondence with Ministers of Mines of the Provinces, he had been given assurances that suggestions to this end would be welcomed.

Mr. W. G. MILLER:—I question whether the idea is feasible, but it would nevertheless be well for such a committee to meet and look into the matter.

Dr. PORTER:—Or to make suggestions to the Governments if desirable.

Major LECKIE:—Much might be done by a Minister of Mines for the Dominion to at least harmonize the existing Provincial Mining Laws.

A paper was then read and discussed, entitled:

Notes on the Utilization of Power Grades of Coal Slack. By D. B. Dowling.

The author explained that the object he had in view in presenting the paper was to suggest some methods whereby the western coals of the prairie or lignites might be utilized to better advantage.

The meeting then adjourned until the following day. In the afternoon a number of members and guests availed themselves of the invitation extended, through the President, by the Hon. Mr. Brodeur, Minister of Marine and Fisheries, to make an excursion on the ice-breaking steamer "Montcalm" to Montmorenci Falls, and thence to Cape Rouge. The local committee provided luncheon on board and a most enjoyable afternoon was thus spent.

ANNUAL DINNER.

The annual dinner was held on Thursday evening in the banqueting hall of the Chateau Frontenac, covers being laid for about sixty. The guests of the evening were: His Honor, Sir Louis Jette, K.C.M.G., Lieutenant-Governor of the Province of Quebec; the Hon. Jean Prevost, Provincial Minister of Mines; Mr. George Garneau, Mayor of Quebec; Dr. James Douglas, of New York, Past-President of the American Institute of Mining Engineers; and Major Shepherd.

The toasts were: The King; the President of the United States; the Lieutenant-Governor, proposed by the Chair and responded to by Sir Louis Jette; the Department of Mines of the Province of Quebec, proposed by the Chair and responded to by the Hon. J. Prevost; the City of Quebec, proposed by the Chair and responded to by Mr. Garneau; the Mineral Industry, proposed by Dr. F. D. Adams, and responded to by Mr. F. Hobart and Mr. H. W. Hixon; Our Guests, proposed by Dr. J. Bonsall Porter, and responded to by Dr. Douglas; the President of the Institute, proposed by Mr. J. E. Hardman and responded to by Mr. G. R. Smith.

The dinner was in every respect a most enjoyable and successful affair.

MORNING SESSION—FRIDAY.

The session opened at 11 o'clock, the President, Mr. G. R. Smith in the Chair.

Papers were read, On the Need of a Topographical Survey of the Dominion of Canada, particularly with reference to the Development of the Economic Resources of the Dominion. By Dr. F. D. Adams.

Some Labatory Experiments in the Electric Smelting of the Titaniferous Iron Ores of Hasting County. By J. W. Evans.

At the close of an interesting discussion on these papers, Major Leckie suggested that in future, in order to save time at Annual Meetings, it would be an advantage to present only abstracts of papers. Furthermore he was of the opinion that all papers should be in the Secretary's hands at least two weeks prior to the Annual Meeting.

Dr. Porter pointed out that members too often fail to realize the necessity of sending their papers to the Secretary's office sufficiently in advance to admit of early publication, and expressed the wish that Major Leckie's remarks could be addressed to the membership at large. He said: "If members could be persuaded to send in their papers in advance, we might not only abbreviate our meeting, but we would have more time for discussion. No one would be better pleased than the Secretary if members would act in future on this suggestion."

PRESENTATION OF PRESIDENT'S GOLD MEDAL.

In presenting the President's Gold Medal to Mr. L. Heber Cole, of McGill University, for the best student's paper presented last year, the President expressed the hope that the offer of awards to students would continue to be an incentive to them to contribute papers to, and take an active interest in, the work of the Institute.

BOUNTIES ON PIG IRON.

The following resolutions, moved by Col. Hay and seconded by Mr. Coste were then passed, after an interesting discussion.

"Resolved that in in the opinion of this Institute, the Dominion Government should enact legislation providing for the payment of a bounty of $3 per ton on pig iron the product of ores raised or mined in Canada or Newfoundland. The Act to remain in force for five years from date of passage; and that a copy of this resolution be forwarded to the Premier, Sir Wilfrid Laurier, and to the Hon. W. S. Fielding, Minister of Finance."

FREE ADMISSION OF BITUMINOUS COAL INTO CENTRAL CANADA.

"Resolved that in the opinion of this Institute bituminous coal should be admitted into Central Canada free of duty when used exclusively for the manufacture of coke for use in blast furnaces producing pig iron, and that a copy of this resolution be forwarded to the Premier, Sir Wilfrid Laurier, and the Hon. W. S. Fielding, Minister of Finance."

The session closed with the presentation and discussion of papers entitled:—

The Education of Mining and Metallurgical Engineers, with special reference to Teaching and Practical Work. By Dr. J. B. Porter;

The Teaching of Metallurgy in College Laboratories. By Dr. Alfred Stansfield.

AFTERNOON SESSION—FRIDAY.

At the request of the President, Mr. Eugene Coste took the Chair.

ELECTION OF OFFICERS AND COUNCIL.

The Scrutineers reported the result of the election of officers and council for the ensuing yearly term as follows:—

President, Mr. Geo. R. Smith, M.L.A., Thetford Mines, Que.

Vice-Presidents—(For one year):—

Dr. F. D. Adams, Montreal.
Major R. G. Leckie, Temagami, Ont.

Vice Presidents—(For two years):—

Frederic Keffer, Greenwood, B.C.
G. Herrick Duggan, Sydney, C.B.

Treasurer—J. Stevenson Brown, Montreal.

Secretary—H. Mortimer-Lamb, Montreal.

Councillors—(For one year):—

Mr. John Blue, Eustis, Que.
Mr. C. J. Coll, Stellarton, N.S.
Mr. Thos. Cantley, New Glascow, N.S.
Mr. Frank B. Smith, Edmonton, Alta.
Mr. J. C. Gwillim, Kingston, Ont.
Mr. Jas. McEvoy, Fernie, B.C.
Mr. W. G. Miller, Toronto, Ont.
Mr. Harry Williams, Danville, Que.

Councillors—(For two years):—

Mr. W. H. Aldridge, Trail, B.C.
Mr. B. A. C. Craig, Toronto, Ont.
Mr. A. M. Hay, Kenora, Ont.
Mr. R. T. Hopper, Montreal, Que.
Mr. Thos. Kiddie, Victoria, B.C.
Dr. A. E. Barlow, Ottawa, Ont.
Dr. J. Bonsall Porter, Montreal, Que.
Mr. W. D. Robb, Amherst, N.S.

The Chairman congratulated the above gentlemen upon their election.

Mr. R. W. BROCK then presented a paper, illustrated by lantern slides, on:—The History of the Rossland District; after which a set of lantern slides illustrating the asbestos industry was shown and the industry described and discussed by Mr. J. J. Penhale. Dr. Porter also showed a number of views of the mining fields of South Africa.

Mr. R. T. HOPPER moved a vote of thanks to Dr. Porter for his services in connection with the Annual Meeting. In seconding the resolution, Mr. J. Stevenson Brown said: "Perhaps no one has a better knowledge than I of the important service Dr. Porter has rendered the Institute during the past three or four weeks, and we could scarcely have had so successful a meeting, under the circumstances of the unfortunate illness of our Secretary, had not

Dr. Porter stepped into the breach and at great personal inconvenience, devoted his time freely and gladly to serve the Institute on this occasion."

Votes of thanks were also passed to the Hon. Mr. Brodeur, for placing the SS. "Montcalm" at the disposition of the Institute; to the Quebec Light Heat and Power Company and to the citizens of Quebec for courtesies and hospitality extended to members during their stay in Quebec; and to Mr. J. Obalski, Chairman of the Dinner Committee.

The Proceedings then terminated.

PAPERS

PROSPECTING FOR IRON ORE IN THE TORBROOK IRON DISTRICT, ANNAPOLIS COUNTY, NOVA SCOTIA.

By W. F. C. Parsons, Londonderry, N.S.

Extent. The territory covered by the titles of The Annapolis Iron Company, Limited, extends practically from the County line between Annapolis and Kings, westerly to the Nicteaux River, a distance of slightly over five miles, and has a width throughout its entire length of about one and a half miles. It may very conveniently be divided into two sections, namely the north section and the south section. The veins run nearly east and west. The north section contains the outcrop of three veins, and the south section the outcrop of two veins.

The north and south outcrops run almost parallel to each other. There is every reason to believe they form the upper edges of a syncline of continuous veins of ore, that is, the outcrop on the north dips under the intervening territory and outcrops again in the south section along the South Mountain.

The northern section has been prospected very extensively. The eastern end has been exploited by the workings of the Leckie Mine, (now operated by the Londonderry Iron & Mining Co.) The main shaft of the mine has been sunk to a depth of 350 feet, levels being started 50 feet apart and extending to the east and west for many hundreds of feet. The lower levels Nos. 3, 4, 5 and 6 are being pushed to the westward in order to open up new territory. The plant at the mine comprises three 40 H.P. boilers and one 80 H.P. boiler, one Lidgerwood hoist and two 12″ x 18″, Allis Chalmers Bullock Co. straight line air compressors, besides air drills pumps, etc., as well as boiler, engine and dry houses, blacksmith and carpenter shops, office and superintendent's house.

About one mile west of the Leckie Shaft a new inclined shaft, called the Hoffman, was started upon what is known as

the shell vein. The width of this vein is about 5½ feet, and its dip about 85 degrees. Sinking was commenced on this vein in December 1905. At the latter end of January, 1906, it was sunk to a depth of 163 feet, at which point it was decided to crosscut to the north for the Leckie Vein, which is about 82 feet distant. This work is now underway. The plant at this shaft consists of one 60 H.P.R.T. boiler, one 12″ x 18″ Allis Chalmers Bullock, Ltd. straight line air compressor and one 14″ x 7″ x 14″ Knowles sinking pump. The size of shaft is 7′ x 14′. It was only necessary to permanently timber this shaft for the first 25 feet. The balance of shaft is timbered with stulls set about 6 feet apart on either side of the skip road. The walls being very hard and regular, very little water was encountered in sinking. It was handled by bailing except on Sundays, when pump was lowered to keep the water out. Sinking averaged over three feet per day, of three 8 hour shifts. The drills used were Ingersoll Sergeant "D" 24, supplied by Allis-Chalmers Bullock, Ltd. of Montreal. These drills proved suitable for this work.

Another inclined shaft, called the Wheelock, situated one mile west of the Hoffman was commenced in November, 1905. This also is sunk upon the shell vein. The width of the vein is 6 feet and its dip was 77 degrees for 63 feet. Then it flattened to 45 degrees for 15 feet. Then to 43 degrees for 16 feet. At the point where the vein flattened, it increased in thickness to 12 feet. At 94 feet the vein suddenly dipped to an angle of 75 degrees, narrowing again to 6 feet. This was followed to a depth of 116 feet, at which point it took another flatter pitch to the south. It was decided to continue sinking upon the line of the 75 degree pitch. This was sunk to a depth of 170 feet, the last 54 feet in rock. It was deemed advisable to sink in rock owing to the numerous changes in the dip. It would be difficult to operate a skip over these changes of grade. At a depth of 155 feet a cross cut tunnel was started to the north to intersect the Leckie Vein, which is estimated to be about 112 feet distant. This work is now underway. When completed a crosscut will be started to the south to locate the lost vein. The sinking of this shaft was a comparatively difficult proposition, owing to the quantity of water encountered. Progress of sinking did not

average over 2 feet per day. The size of the inclined shaft is 7′ x 14′. The plant is a duplicate of that at the Hoffman Shaft.

It is the intention as soon as the Leckie Vein is intersected at these two shafts to drift upon the veins east and west so as to prove the continuity of the same.

Two boreholes were put down by the Nova Scotia Steel Co. in this district. One, a diamond drill hole, is situated about 550 feet west of the Hoffman Shaft. From Government records, this hole proved the shell vein at this point to be 5′2″ wide and the Leckie about 6 feet. There is also a third vein about 2 feet.

The second hole is a 5″ Calyx, sunk to a depth of 387 feet on the farm of Josephine Wheelock, about 1500 feet east of the Wheelock Shaft. The Government records show that at a depth of 330 feet from the surface, ore was intersected, and at a depth of 387 feet this hole was still in ore. It is estimated that the shell vein at this point is at least 9 feet wide and of good quality, iron tenor 49.5%. Messrs. Brookfield & Corbett, who owned the property at this time, continued this hole for another 7 feet. This core showed indications of approaching the foot wall. However, the analysis showed the ore to run considerably over 40% metallic iron.

A borehole was sunk some years ago by Messrs. Brookfield & Corbett on the farm of Fletcher Wheelock. This hole is about 350 ft. east of the Wheelock Shaft and 40 feet south of the shell vein. The Nova Scotia Government records show that it cut the three veins, shell vein at 112 feet, width of vein 15 feet: Leckie vein at 330 feet, width 9 feet: 3rd vein 435 feet, width of ore 14 feet.

It should be stated that the shell vein from the Hoffman to the Wheelock Shaft is a magnetic ore due no doubt to the proximity of diorite.

The following analyses shows the quality of the ore in this district, that is, from the Leckie Mine to the Wheelock Shaft where the prospecting work has been confined. From the numerous samples taken from the Leckie Mine, the analysis may be stated as Metallic iron 52.00%, Phosphorus 1.15%, Sulphur 0.02%, Manganese 0.10%, Insol. 13.5%, Magnesia 0.30%, Lime 2.5%.

Hoffman Shaft on shell vein iron 47.47, phos. 1.32, insol. 17.23.

Wheelock Shaft on shell vein iron 49.00%, insol. 15.28, phos. 1.02, lime 3.35, magnesia 0.57.

Page & Stearns farm, shell vein, iron 50.00%, insoluble 16.00.

Leckie vein, iron 50.55%, insoluble 13.65.

George Holland, shell vein.

Leckie Vein, iron 51.95, insol. 11.57, phos. 1.517, lime 3,21.

Southern section. This section, mentioned before as being the southern outcrop of syncline, extends three miles and contains an area of two and three quarter square miles. It has not been as thoroughly prospected as the northern one. The ore is a black magnetite of varying qualities, the western portion of the area being the better. Analyses of samples taken from surface pits, run as high as 50% metallic iron and as low as 36%.

NOTES ON THE PRODUCTION AND USES OF CANADIAN CHROME.

By W. H. Edwards, Black Lake, Que.

Chrome iron is found in large quantities in the serpentine belt in the Eastern Townships, Quebec, between Disraeli and Broughton, in the hills to the southeast of the Quebec Central Railway, but it is worked commercially only in the Black Lake district. Until recent years no serious operations had been undertaken for its production, but it has been clearly shown that it should take a high rank among the mineral resources of the province.

There are several mines through the Black Lake district which are being very successfully developed and one, that of the Black Lake Chrome & Asbestos Co., has gone beyond the experimental stage and has become an important factor in the chrome trade of this continent. The company has a mill of thirty stamps for the concentration of the waste from their pits and is producing a very high class chrome concentrate running 50–54% chromium sesquioxide, which is coming into direct competition with the high grade Caledonia ores. Indeed all the chrome treated in this way through the district is of very high quality.

The method of mining and treating the ore is the same throughout the district and is very simple. After it comes from the pit it is sorted and all that will run over 40% Cr_2O_3 is put aside as crude. This product is divided into two grades all below 47% being No. 2 and all above it No. 1. The balance, or all ore testing below 40% and over 10% goes to the mill as waste. Here it goes through a jaw crusher and under the stamps. After it will pass through a No. 22 mesh screen it goes to the Wilfley tables; the best of the tailings from the tables are run on to another table and the resulting concentrate is called No. 2, having a percentage in Cr_2O_3 of 40–43%.

It is not possible to state whether the ore in this district has the same formation throughout as the only place where it has been followed for any distance is in the No. 1 pit of the Black Lake Chrome & Asbestos Co. This pit has a present depth of 350 feet and there is every reason to believe that the ore is in a vein and not, as has been thought to be the case in all chrome deposits, in the form of a pocket. The strike of the vein is about E. and W.; the underline is about 2′ in 6′, while the width has varied greatly. At the surface it was only 4′, at the 150′ level it was 20′ and to-day at the 350′ level it is 175′. The thickness has gradually increased from 3′ at the surface to 30′ at the 350′ level.

The amount of chrome shipped from the Black Lake district during 1905 was as follows:—

Black Lake Chrome & Asbestos Co	7,800 tons.
American Chrome Co.	225 "
Canadian Chrome Co	252 "
Montreal Chrome Co.	200 "
	8,477

Making a total of 8,477 tons, an increase of over three thousand tons over 1904. This has practically all gone to the United States where the yearly consumption is about 80,000 tons.

The uses of chromite are many and varied and it is not possible to more than touch on the principal points.

The chief use of high class chromite is in the manufacture of soda and potash chromates and bichromates, which are used as the base for the manufacture of the various other chromium salts. It is also used in the manufacture of ferrochrome for the hardening of iron and steel and for this purpose is coming into more extensive use year by year.

Besides their use in making chrome compounds, chromates and bi-chromates are also extensively used as pigments in dyeing and printing. Another important process in which chrome is becoming widely used is that of chrome tanning in which it replaces the tannin of the older bark process.

The principle of the manufacture of bi-chromates depends on the roasting of very finely pulverized chrome ore of over 50% or more Cr_3O_3, in a reverbatory furnace after very thorough mixing with burnt lime and either an alkali sulphate or a carbonate.

The product of this oxidizing roast is then treated with hot water which dissolves out the chromate. After the solution of chromate has been concentrated, sufficient strong sulphuric acid is added to neutralize the alkali. Bi-chromate and sulphate are formed and part of the latter is precipitated from the solution and the liquid decanted off and the crystals washed. The liquid is concentrated now as far as possible and filtered while hot to remove any sulphate that may be in it in the form of a precipitate and the bi-chromate is allowed to crystallize out. The sulphate, obtained as a by-product, is used again in treating fresh chromite as it usually contains too much chromate to make it valuable as an article of commerce.

For the purpose of manufacturing ferrochrome the ore used must have a ratio of 1 of iron to 3 of chrome. The principle of the manufacture of this article is simply the reduction of the oxides to their metals and the fluxing off of the impurities. This may be done either with charcoal in graphite crucibles or by the electric furnace. It is also made by the Goldschmidt Thermit Process.

In *Mineral Industry*, 1903 Vol. 2, the uses of bi-chromate are spoken of as follows:—

"Potassium bi-chromate is used extensively in the preparation of chrome yellow and chrome orange which are employed as pigments in calico printing; chrome black used in dyeing; for the oxidation of caoutchouc and Berlin blue; the discharge of indigo blue; the bleaching of palm oil and other fatty substances; the preparation of mixtures for the heads of lucifer matches and the preparation of mercurous chromate and chromic oxide, which are used as green pigments in the ceramic art. Potassium chromate is further used in the manufacture of analine colors and chlorine gas, in defuseling brandy and for many other purposes in the chemical industry, where it is an exceedingly important agent, etc." The article also gives the methods of preparation of the various compounds mentioned.

The lower grade chromite ores are used as refractory basic linings for furnaces both reverbatory and blast, and in the manufacture of chrome bricks for the same purpose.

The Canadian ore is particularly adapted for furnace lining as the silica present in it is combined with magnesia. Strange

to say the presence of a fairly large amount of silica was used as an argument against the Canadian ore when it first came on the market; but tests made by many steel companies in the United States show that this ore lasts nearly a third longer than foreign ores.

The principal competitors of the Canadian ore have been the mines in New Caledonia in high class ore and the Turkish and Russian mines in the low class; but owing to their distance the Canadian mine owners have always been able to undersell them. If the progress of the past four years keeps up there is no reason to doubt that Canada will be able to dictate the price of chrome in the markets of the world.

SOME OBSERVATIONS RELATIVE TO THE OCCURRENCE OF DEPOSITS OF COPPER ORE ON VANCOUVER ISLAND, AND OTHER PORTIONS OF THE PACIFIC COAST.

By Wm. M. Brewer. Victoria, B.C.

For the past eight years the author has been engaged in the examination of copper ore deposits and their development on the Pacific Coast. In a future paper he hopes to give a complete and detailed account of the results of his observations, but for the present he wishes merely to set forth a brief outline of the character and extent of these deposits.

Copper ore has been noticed to occur in five classes of deposits.

First.—Bornite ore accompanied by some carbonates, chalcocite, and at the deeper levels, chalcopyrite, which occurs in contact deposits between crystalline limestone and igneous rocks, usually felsite associated with garnetite.

Second.—Chalcopyrite ore which occurs in a magnetite matrix in deposits of lenticular structure in fissures in the basic igneous rocks.

Third.—Chalcopyrite ore usually in a magnetite matrix which occurs as contact deposits between crystalline limestone, slate or schist, and basic igneous rocks.

Fourth.—Chalcopyrite ore occurring in association with iron pyrites, barite or heavy spar, and a small percentage of lime which has only been found up to date in a schist country rock.

Fifth.—Pyrrhotite ore carrying low copper values sometimes in a gangue composed of a high percentage of epidote, garnet, amphibolite and some calspar, which occurs either in fissures in basic igneous rocks, or else at the contact of crystalline limestone and the igneous rocks.

The author has not observed along this coast any deposit of copper ore with the true gossan outcrop resultant from the weathering of limonite or brown hematite iron ore, such as is found in

the Ducktown, Tennessee, and many other copper ore deposit and which usually overlays a zone carrying black oxide of copper, and native copper below which occurs chalcopyrite. The reason for this is that the zone of oxidation has generally been removed by erosion.

In the early history of prospecting for copper ore it was natural that men acquainted with the occurrences of ore underlying gossan outcroppings should presume that magnetite and possibly pyrrhotite outcroppings indicated deposits of valuable copper ore at depth, but at the present time most of us have found out that any such theory is not founded on fact. These minerals are found to be the matrix or gangue associated with the chalcopyrite ore, particles and masses of which are found shot through the bodies of magnetite and pyrrhotite, but the author has never seen these minerals at depth give place to solid copper ores. On the other hand bodies of magnetite which carried a substantial percentage of chalcopyrite, almost theoretically pure, near the surface sometimes give out entirely at depth leaving only a narrow seam of calcspar on the foot wall of the fissure in diorite which has previously been filled to a width of eight feet by the magnetite and chalcopyrite.

Let us take up the consideration of the various occurrences of copper ores in the rotation in which they are referred to in the list already given.

First.—The bodies of bornite ore accompanied by variable proportions of copper carbonates, chalcocite and at deeper levels by chalcopyrite.

The localities in which such deposits have already been found are Texada Island, Sidney Inlet on the West Coast of Vancouver Island, Gribbel Island, and White Horse in the Yukon Territory. As these deposits have been already discussed several times in papers read before Institutes of Mining Engineers and in others published in technical journals, in this paper only brief mention will be made to results as shown from the latest and deepest development work.

The deepest workings on deposits of this character of ore are on the Copper Queen and Marble Bay Mines on Texada Island, on each of which the workings have been carried below the 600 foot levels, while on the Copper King in the White Horse

Belt the ore has been followed down to 200 feet on the incline of the footwall, about 45 degrees.

In each of these cases the ore body has been found to be strong and giving every indication of maintaining its continuity for a still greater but undetermined depth. Its grade has not deteriorated, but instead on all the properties mentioned has increased in value. In the Texada Island properties the increase has been in the gold contents of the ore, while on the White Horse property the increase has been in a greater percentage of chalcocite as compared with that found on the 100 foot level.

Prospecting carried on during 1905 in the mountains adjacent to Gardner Canal in the neighborhood of Gribbel Island exposed outcroppings of bornite ore hitherto unknown. This fact may have an important bearing because it tends to establish a relationship between the various known deposits of this character of ore along the Coast, and indicates that wherever a zone is found in which occurs crystalline limestone and felsite, the prospector may reasonably expect to find paying deposits of copper ore.

The question naturally suggests itself as to what is the extent of such zone or zones and the probabilities with regard to continuity. So far as at present known the occurrences of such zones are few and far between, the extent of each being limited to comparatively small dimensions when compared with the other mineralized zones along the coast. Except in the White Horse Belt the continuity of the contact between the crystalline limestone and felsite is confined within the boundaries of a single mineral claim, and often the contact cannot be traced even to that length. The ore bodies do not generally maintain the same continuity as the contacts but occur as lenses isolated from each other and rarely exceeding 100 feet in length.

Consequently this class of copper bearing ore deposits, although in every instance where systematic exploitation has been made they have proved of considerable commercial value, cannot be included among the big mines, but rather stand in a class by themselves as profitable small ones.

The White Horse Belt possesses the possibility of developing some larger mines because several claims along the line of strike of the contact can be grouped together and developed as one property.

Until more thorough geological investigations are made and surveys worked out in detail, or the coast line more thoroughly prospected and the relationship if any between these various zones established, it is impossible to say how valuable or important this class of ore bodies may become.

The second class of ore bodies which comprises the deposits of chalcopyrite ore, occurring in a gangue or matrix of magnetite in fissures in basic igneous rocks, is one having a large number of representatives, especially on Vancouver and Prince of Wales Islands. Unfortunately development work on some of these has demonstrated that the ore bodies have pinched out at comparatively shallow depths. For this reason operators generally have lost confidence to such an extent that at the present time but very little work is being done on any ore body belonging to this class.

The surface outcroppings in almost every instance where such an ore body has been discovered have indicated such favourable conditions as regards the extent of the outcropping and grade of the ore that a few years ago this class of ore bodies was a particular favorite among the prospectors.

As a matter of fact very few ore bodies of this character have received the attention they warranted.

The question of genesis of such an ore body appears to me to be one of vital importance, and nowhere on the Pacific Coast has sufficient research been made to establish the theory on which to build a reliable opinion as to the genesis.

From a casual examination it would appear as though the magnetite was a direct resultant from the cooling of the molten mass of basic rock and that at or about the same time certain agencies had been at work which caused the deposition of chalcopyrite in particles and masses disseminated with more or less less regularity throughout the mass of magnetite.

Whether such agencies worked on the ascending or descending theory is to my mind the most important feature to be demonstrated with regard to this class of ore bodies, and the development has not yet been sufficient to warrant the expression of an unqualified opinion on this subject. One thing though is certain that if the deposition of the chalcopyrite had its origin from ascending gases, vapors and solutions, then it is only reasonable

to suppose that the ore bodies would maintain continuity to considerable depth, whereas if the origin is from descending waters charged with copper, which have percolated through the cooling mass of magnetite, it would be equally as reasonable to expect that such ore bodies would not maintain continuity except to such depth as channels extended through which the waters could percolate.

There is one phase of this problem though which must not be overlooked. It is the fact that so far as the author's observations have gone no chalcopyrite occurs outside of the mass of magnetite, and at the point where the magnetite disappears the chalcopyrite also disappears; therefore the conclusion presents itself that the magnetite must be to a very great extent responsible for the chalcopyrite associated with it, otherwise one would expect to find the copper ore below the magnetite just as it is found below the gossan outcroppings derived from limonite.

In several instances which have come under the author's observations there is no question but that this class of ore bodies possesses very considerable commercial value provided they are situated close to salt water, but where the question of transportation by means of long surface or aerial tramways has to be considered, operators, because of lack of confidence in the permanency of such ore bodies at depth, hesitate to make the necessary investment to perform sufficient development work required to block out a large enough tonnage of ore to warrant the installation of expensive tramways.

The fact that along the coast the zone of oxidation on the present surface is extremely shallow except in some isolated locations has also undoubtedly influenced operators and tended to increase their lack of confidence in this particular class of ore bodies. There is no use denying the fact that many deposits belonging to this class have the appearance of being the lower portion of a lenticular mass, the upper portion of which has been carried off by erosion, but up to the present time in every instance where development has been attempted, operations have been suspended at the point where the ore body had pinched, and no exploitation carried on to determine whether other lenses occur.

The third class of ore bodies, that in which chalcopyrite ore occurs at the contact of crystalline limestone, slate or schist and

igneous rocks will probably prove to be the most important because of being the most extensive and permanent occurrences of copper ore along the coast.

In this class of deposits the chalcopyrite generally occurs in a magnetite gangue, as well as in a gangue composed of garnetiferous felsite. Usually only one wall is well defined, especially so is this the case when the gangue is garnetiferous felsite. In such cases the limestone wall is well defined and considerable gouge occurs between the ore and the limestone, but on the opposite side the solid ore gradually gives place to garnetite carrying a fair percentage of ore, which in its turn grades into perfectly barren garnetite thereby giving the impression that the mode of deposition of the ore was by replacement and that apparently the garnetite had a stronger influence in the formation of the ore body than the limestone. Owing to the solubility of the limestone one would look for masses and pockets of ore to occupy caves in that rock, but I have only noticed such as very exceptional occurrences, usually the limestone shows an almost perfectly clean and regular cleavage plane on which the gouge lying between it and the ore body has formed.

Where slate or schist forms a contact with igneous rock and the ore body occurs in the contact the deposits although of lenticular structure are nearly always of exceptionally great dimensions. As illustrations of this fact there are the Britannia Mines on Howe Sound about 40 miles north of Vancouver; the Beatson Group on La Touche Island, Alaska, and the Gladhaugh Mine at Ellamar, Prince William Sound, Alaska.

On the first named of these properties the main ore body known as the Mammoth Bluff has been cross cut more than 100 feet, the tunnel having been driven in ore all the way. This ore is extremely low grade in both copper and gold values and occurs in a highly siliceous gangue and should really be classed as iron pyrites carrying a percentage of chalcopyrite sufficient to give it commercial value providing a successful concentration can be made. While this Mammoth Bluff ore body is the largest in extent on the property yet there are other bodies of much higher grade ore but more limited in extent. The Mammoth Bluff is practically a huge mass of ore about 600 feet long, 200 feet high and has been cross cut upwards of 100 feet. These dimensions

are taken from the base to the apex of the bluff, and nothing is yet known relative to the depth. In fact no sinking has been done on the property unless quite recently.

The property known as the Beatson Mine on La Touche Island, Alaska, is apparently destined to become the most important copper mine in Alaska because the ore body possesses both great extent and high grade. A bluff of ore occurs here from which shipments in 250 ton lots have yielded an average of about 10% in copper. Under this bluff a cross cut tunnel has been driven which determines that the ore body is about 200 feet in width. From this tunnel an upraise has been made to the floor of a quarry in the face of the bluff. This upraise is made in ore. A second crosscut tunnel is being driven at a level 100 feet lower than the upper one, but has not yet been driven far enough to intersect the ore body, but when this is done, if the conditions on that level are as favourable as on the upper one, where a drift has been run in ore about 150 feet there can be estimated a probable tonnage almost, if not quite equal, to that on the Mammoth Bluff on the Britannia, and of a value far exceeding the ore body on that property.

The country rock in which the Beatson ore body occurs is a slate, (graphitic in places) on the hanging wall side, and a greenstone on the foot wall. The zone of slate is quite wide, and extends for several hundred feet in length but there are several intrusions of igneous rock some of which have apparently caused faulting in the belt of slate. No geological survey has yet been made to determine the details of the conditions surrounding this interesting property. Probably the latter supposition will prove the correct one.

The third illustration mentioned as representing this class of ore bodies is the Gladhaugh Mine, at Ellamar on Prince William Sound, Alaska. The development at this property has determined that continuity in depth may reasonably be looked for in such ore bodies because the ore is found at the 500 foot, the lowest level to which the shaft has yet been sunk.

The fourth class of copper ore deposits, that in which chalcopyrite ore occurs in a gangue composed of iron pyrites, barite, silica, and some lime is, so far as at present known, peculiar to the Mount Sicker District on Vancouver Island. The country

rock is a sericite schist with numerous intrusions of igneous rocks, generally diorite, sometimes having a porphyritic structure. A portion of the schist is graphitic, and the ore bodies are generally in this portion of the schist belt.

The grade of the ore is higher than the general run of chalcopyrite deposits on the Pacific Coast, and has averaged over 4% copper, 0.17 oz. gold, 4 oz. silver per ton as shown by the returns from about 250,000 tons of ore smelted during the past four years.

These ore bodies have been more systematically and thoroughly developed than any other on the coast. They present a most interesting subject for study from a geological standpoint, because of the many pronounced evidences of extensive faulting and the fact that movements have taken place since the formation of the ore deposits as well as prior thereto. This latter condition is attested to by the numerous slickensided cleavage planes exposed throughout the ore bodies as mining operations have progressed, and that the former condition exists is apparent from a study of the surface although the geology in detail has never been worked out.

The ore apparently occurs in large lenses but these are so closely allied with each other along the line of strike that in a drift on the Tyee Mine some 1,300 feet in length it appears at a casual glance that there has been no break in the continuity of the ore, however, on the Lenora mineral claim adjoining the Tyee on the west the lenticular structure is more pronounced.

The interesting feature both from a commercial as well as a scientific standpoint is the fact that no ore has been discovered between the 300 and the 1,000 foot levels on the Tyee, although the ore body above the 300 foot level often reaches a width of about 50 feet of clean solid shipping ore, and has been found practically continuous for a length of about 1,300 feet. Similar conditions apply to the ore body on the Lenora Mine except that the length of the deposit was not nearly so great, nor has the exploitation been carried on so thoroughly, systematically or extensively in search of other ore bodies as has been done on the Tyee Mine.

On that property sinking has been carried to a depth of 1,000 feet, on which level an ore body has recently been exposed and is being exploited. Levels have been opened every 100 feet,

and considerable crosscutting and drifting done on each level. This drastic development work is being carried on continuously and in consequence, the underground workings offer a splendid opportunity for making a thorough study of the geological conditions.

Unfortunately the owners of adjoining properties have suspended development work, apparently with the intention of awaiting the outcome of that being prosecuted by the Tyee Company, consequently the full extent of the ore bearing zone is not known at this time. The schist formation though, can be traced on the surface through Mount Sicker, and westerly across the valley of the Chemainus River on to Mount Brenton, except where intrusive masses and dykes of igneous rocks have cut it off. Even then the same character of schist is found towards the south in which direction it has apparently been thrust.

Another feature, almost unique in mining, is the fact that on the Tyee property there is no second grade ore or waste in the ore body itself. The entire width between the boundaries or walls, is a solid mass of clean ore. The walls are well defined, both being schist, and have considerable gouge between them and the ore, so that in mining the latter is easily broken away.

The fifth class of ore bodies is that in which occurs pyrrhotite ore carrying low copper values sometimes in a gangue composed of a high percentage of epidote, garnet, amphibolite and some calcspar occurring either in fissures in basic igneous rocks or else at the contact of crystalline limestone and igneous rocks.

In this class of ore bodies the copper values are carried by masses and particles of chalcopyrite disseminated with variable regularity through the pyrrhotite. The writer has observed instances where at comparatively shallow depth the pyrrhotite has apparently been replaced (this word is not used here with the same sense as is understood generally in mining parlance) by lenses of quartz carrying chalcopyrite of such high grade as to show by assay as much as fifteen per cent. in copper to the ton, but usually at depth the pyrrhotite grades into marcasite carrying a low percentage of chalcopyrite together with low gold and silver values.

In appearance the pyrrhotite from some of these ore bodies resembles so strongly the nickel bearing ores of the Sudbury District that mining engineers well acquainted with the Sudbury

ores have expressed the opinion that the pyrrhotite found especially on the west coast of Vancouver Island was nickel bearing to a commercial extent, but several assays made for nickel have shown that this metal is only present in such minute quantities as to yield merely a trace.

On Prince of Wales Island in Alaska on the east coast of the Island, as well as on the west coast of Vancouver Island there are several illustrations of ore bodies of this character, but up to the present time none of these have been developed beyond a comparatively shallow depth, about 150 feet being the deepest. From this level ore of a commercial grade is being shipped by the Niblack Copper Company. On most of the other properties of this character the greatest depth attained is less than 100 feet.

The low value of this class of ore and the difficulty of successfully sorting it have discouraged operators from investing in such properties, but the high price of copper during recent months has proved an incentive and at present a few of these properties are being worked to such an extent that in the near future many material facts will have been ascertained.

The perfection of magnetic separation is destined in the future to solve the problem of concentration, not only with regard to this class of ore bodies but also with regard to the bodies of magnetite carrying chalcopyrite.

NOTE ON WINDY ARM SILVER BEARING VEINS.

By R. G. McConnell, Geological Survey, Ottawa.

A mineral area of considerable promise was opened up during the past season on Windy Arm, Tagish lake, Yukon Territory. Silver bearing veins were found in this district by prospectors bound for the Klondike as far back as 1900. The gold excitement prevailing at that time prevented much interest being taken in the discovery and its development was delayed until the past season,

The mineral area is situated in a group of mountains lying between Windy Arm, a southern arm of Tagish Lake, and Lake Bennett. It is easily accessible, as Conrad City on Windy Arm, the present centre of mining activity is less than ten miles distant from Caribou Crossing on the line of the White Pass and Yukon Railway and not more than seventy five miles distant from tide water at the head of Lynn Canal.

Geology.

The geology of the district has not been studied in detail and only a bare outline can be given here. The great granite batholith which fringes the Coast range from the International boundary northward to a point beyond Lynn Canal is bordered on the landward side in the vicinity of Windy Arm by a group of argillites and sandstones largely tufaceous in origin, associated with conglomerates, and probably referrable to the Jurassic. These are followed going eastward by a more altered series consisting of slates, quartzites and cherts interbanded with crystalline limestones which are referred to the Upper Paleozoic. Both series are tilted at large angles and follow in their strike the general direction of the adjacent long granite batholith of the Coast range.

The older clastic series is cut by granite dykes and bosses

similar in character to the Coast range granite mass and is separated from the younger series on Windy Arm by a basic igneous rock usually porphyritic in character and younger than the granite. The latter constitutes the principal ore-bearing rock of the district. The few sections examined show it to be a decomposed augite porphyrite apparently passing at one point into a gabbro. It is heavily charged with iron and in many places weathers to a rusty colour. The porphyrite outcrops along Windy Arm for a distance of four miles and is traceable in a wide band across the mountains north westward to Lake Bennett.

THE VEINS.

The largest and most persistent veins so far discovered occur in the porphyrite area. They are not however confined to this formation as a few occur in the granite and some also in the slate. The veins occupy clean cut fissures with regular walls often slickensided and groved. They are comparatively narrow but exhibit as a rule great persistency in strike. The Uranus vein with a width of from one to four feet has been traced by small openings and surface showings for a distance of about 1500 feet and may extend much farther, while the Montana vein with a maximum width of five feet in the portion explored has apparently been cut at a distance of 1600 feet from the main workings. The Venus No. 2 lead, the largest seen by the writer, has a width of nine feet at two openings about four hundred feet apart, and numerous other veins such as the M and M, the Joe Petty and Venus No. 1 are traceable by surface outcrops for several hundred feet. Portions of all these veins are concealed by slide rock and their full lengths have not been ascertained.

The veins show no general parallelism in either dip or strike. The strikes of the veins examined vary fully 80° and the dips range from 10° to 50°.

The gangue in all the veins is mainly quartz. In a few instances portions of the vein filling consist of alternating layers of quartz and silicified and altered country rock. The latter in such cases is always heavily mineralized, usually with iron, and weathers to a rusty colour.

The metallic content of the vein is exceedingly varied as

silver, copper, lead, iron, arsenic and zinc minerals are all represented.

The silver minerals recognized include native silver, argentite, stephanite, freibergite and pyrargyrite. Native silver, argentite and stephanite are comparatively rare while pyrargyrite and freibergite occur in most of the veins and in some of them constitute the principal source of the silver.

Lead minerals are represented by galena and copper by tetrahedrite. Both minerals are highly argentiferous. Chalcopyrite and native copper occur in small veins east of Windy Arm. Iron pyrites is abundant in most of the veins and in some of them is reported to carry gold values. Arsenopyrite is also usually present in considerable quantities in the larger veins. Zinc blende occurs sparingly in most of the veins examined.

MINING DEVELOPMENT.

The amount of development work done in the camp so far is small and has been confined principally to the Montana and Uranus veins, both belonging to the Conrad Consolidated Company.

The Montana vein is situated on a bare hillside 1700 feet above timber line, 3700 feet above Windy Arm and 5860 ft. above the sea. An aerial tramway four miles in length connecting it with Conrad City on the lake shore was nearly completed several months ago. No road has been built as it is intended to use the tram to bring supplies up to the mine. At present the supplies and material needed including firewood are packed up on horses.

The principal workings consist of a tunnel 180 feet in length. The tunnel pierces 50 feet of slide rock then meets and follows the vein. A small fault with a displacement of 7 feet was encountered at one point. The vein strikes N. 43 W. and dips from 10° to 12° to the S. W. The width of the vein increases from about two feet near the mouth of the drift to nearly four feet at the face. Some stoping has been done and a considerable quantity of ore has been shipped.

The ore minerals include native silver, pyrargyrite, argentite, freibergite, tetrahedrite and iron and arsenical pyrites. The

distribution of the minerals through the quartz gangue is somewhat irregular. In places, especially near the walls the vein matter is so thoroughly impregnated with silver and silver bearing minerals that it is rich enough to ship without sorting, that is, contains silver values of $80.00 per ton and over. The leaner portions of the vein require concentration.

Work has been going on for some time on a second tunnel intended to cut the Montana vein 1600 feet N.W. from the main workings. It has been reported that the vein or at least a vein in the same strike has been reached.

The Uranus vein is situated about a mile south of the Montana vein and just above the forks of Pooly creek. The vein crosses a high ridge separating the two branches of the creek and is thus exposed naturally in depth for some hundreds of feet. It is traceable for some 1500 feet, the width varying from a few inches to four feet. The Uranus vein carries more galena than the Montana vein and smaller quantities of the high grade silver minerals.

The M and M situated half a mile below the Uranus in the same valley is a type of the smaller veins in the camp. Its width seldom exceeds fifteen inches yet it is traceable on the surface for several hundred feet. Its full length is not known as its extremities are concealed by slide rock. The M and M vein is especially rich in places in high grade silver minerals such as pyrargyrite, stephanite, and freibergite. The gangue consists entirely of quartz.

The mineral belt as outlined last autumn extends from Red Deer mountain northward along Windy Arm to the Big Thing group on the north fork of Montana creek.

The width of the hill averages about a mile. Over a hundred claims have been staked in this area on veins ranging in width from a few inches to nine feet. The mineralization of the vein is very irregular and no estimate of their average values could be made. It is evident however that most of the vein material will require concentration and arrangements are already being made by the Conrad Consolidated Company for the erection of one or more concentrators on the lake shore. Most of the veins are situated on steep slopes high above the lake and

the transportation of the ores to the lake shore by means of aerial trams offers no especial difficulty.

While it is risky to theorize about the future of a camp in which so little development has been done as in the one under discussion it is safe to say that the prospects are very encouraging and warrant the belief that some of the larger veins at least will be developed into mines.

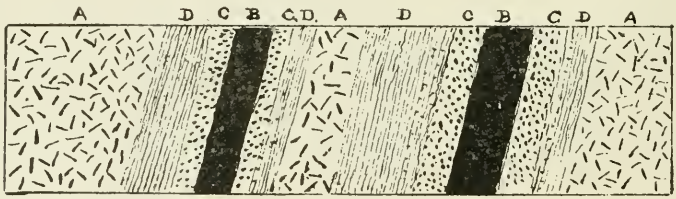
THE LOST PACKER COPPER GOLD LODE.

By E. P. Jennings, Salt Lake City, Utah.

This remarkable lode is located in Loon Creek Mining District, Custer County, Idaho, 25 miles north west of the town of Custer, and 120 miles west of Mackay, a station on a branch of the Oregon Short Line Railroad.

The District was a noted placer camp 35 years ago, then abandoned until 1902, when the lode was discovered and bodies of chalcopyrite, containing 2 to 10 ozs., of gold were opened and shipped by pack train and wagon to the railroad at Mackay, thence to the Salt Lake City smelters.

Sufficient ore was produced in two years to pay all the cost of development, which placed large bodies of chalcopyrite in sight.



SECTION LOST PACKER LODE
A. GRANITE. B. COMPACT CHALCOPYRITE.
C. LEAN ORE. D. SERICITE-CHLORITE SCHIST

The mine is situated on the southern slope of Packer Mountain, which rises 2,000 feet above Canyon Creek, a small tributary of Loon Creek, giving ample opportunity for development by adits, six of which have been driven, the lowest exposing the ore 750 feet below the outcrop.

Packer Mountain is a complex of mica schists, knobs and bosses of granite and dikes of felsite and aplite, with its summit covered by a heavy sheet of rhyolite.

This portion of Idaho is extremely rugged; the mountains having an elevation of over 10,000 feet, with deep valleys and canyons.

The lode occupies a shear zone, which has been traced from near the bed of Canyon Creek to the rhyolite sheet capping the summit of the hill, a distance of 5,000 feet. The zone has a minimum width of 30 feet, and strikes N. 5° E., with a dip of 77° W., and cuts both the granite and mica schist, but is intersected and faulted by the intrusive aplite and felsite dykes.

The ore is chalcopyrite containing from 2 to 20 ozs. of gold and a small amount of silver. The high grade ore is compact and massive, occurring in well defined shoots, 100 feet long and 6 feet maximum width, near the foot wall, continuous in depth to the lowest workings; another body of ore occurs near the hanging wall of the lode and separated from the foot wall shoots by 25 feet of mixed ore, schists and partially altered granite. These high grade ore bodies, averaging 15 per cent. copper, are enclosed in bodies of lean ore that are practically continuous for the full length of the tunnels and are mixtures of chalcopyrite, granular quartz and chlorite-sericite schists; the amount of chalcopyrite becoming less as the walls are approached.

A narrow band of sericitic granite is intercalated between bands of schist near the centre of the lode. These schist bands contain granular quartz, sericite and chlorite with small amounts of chalcopyrite.

The lode has been subjected to movements subsequent to its mineralization, both along its strike, as evidenced by the many "slips" and slickenside surfaces, particularly at the contact of the solid chalcopyrite and the low grade ore, and also by transverse faults. A nearly horizontal felsite dike 20 feet thick displaces the ore 5 feet to the west, between the 2nd and 3rd levels; a short distance below this dike two faults occur nearly parallel to it and also displace the lode a few feet to the west. The lode is also faulted by two aplite dikes; one near its north end with an E–W strike, displacing it 20 feet to the west and the second, several hundred feet south of the first dike, that has a strike of N. 20° E. This latter dike faults both the lode and the horizontal felsite dike 5 or 6 feet.

The following minerals have been recognized in the lode: Gold and silver bearing chalcopyrite, bornite, native copper, quartz, sericite, chlorite, barite, calcite, with malachite stains, hematite and limonite in the zone of oxidation. Pyrite, an almost universal lode mineral, is absent.

The zone of oxidation is 30 to 40 feet thick, resting directly on the unaltered sulphides that present no evidence of secondary enrichment more than the occurrence of thin coatings of bornite in a few places and metallic copper in the quartz ore near the crossing of the aplite dike. Erosion has closely followed the weathering of the lode on this precipitious hill side; this in connection with the compact nature of the ore and lode filling, is unfavorable for secondary enrichment.

The axes of the ore shoots coincide with the principal shear planes; the ore completely replacing the original granite, which may have been crushed by the formation of the shearing fractures, forming deposits of compact chalcopyrite. On either side of these shoots and separated from them by post-mineral slip-planes, the rock is more or less impregnated with chalcopyrite. Thin sections of this material show grains of quartz enclosed in sericite with chalcopyrite in irregular masses disseminated through the sericite and penetrating seams in the quartz. The quartz is evidently an original mineral of the granite and the sericite an alternation product of the feldspar. Thin sections from different portions of the lode and the granite walls exhibit abundant sericite and small amounts of chalcopyrite, the amount of the latter depending on its position in regard to the principal fractures.

The action of the mineralization processes was of too short duration to completely mineralize the shear zone and a complex vein resulted with the principal mineralization along those fractures that offered the least resistance to the solution.

There is no evidence that any portion of the lode was an open fissure, but it is rather a replacement of the more highly brecciated portions of the shear zone with an abundant formation of sericite replacing the feldspar and ferro-magnesian

minerals. It can be classed with those metasomatic deposits of the sericitic, copper-gold type as described by Lindgren.*

I infer that the formation of the shear zone and its mineralization followed closely the granite intrusion, and that thermal waters as the last phase of the vulcanism producing the intrusions of granite, were the mineralizing agents. The nature of these solutions is doubtful, but from the amount of sericite formed, they must have been rich in potassium salts, and contained gold, silver, copper, iron and sulphur, but were deficient in silica unless this substance was held in solution by an excess of potassium carbonate and deposited in the upper portions of the lode which are now eroded.

The remarkable features of the lode are: the absence of all primary sulphides but chalcopyrite which is everywhere present; the scarcity of secondary or vein quartz and all common gangue minerals that are directly precipitated from mineralizing solutions. The quartz present was undoubtedly a constituent of the original granite and the chlorite and sericite are derived from the hornblende and feldspar of the same rock.

The later eruptives had no known effect on the mineralization beyond an increase in the gold content of the ore near the felsite dike, but their mechanical effects are shown by the numerous faults and slips and schistose structure of portions of the lode.

My deductions are based on observations made during a brief visit in 1904, supplemented by information concerning later developments furnished me by John P. Boyle, Superintendent of the mine and L. Webster Wickes, Mining Engineer, and I also extend my thanks to both gentlemen for samples of ore and lode material.

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*W. Lindgren: Metasomatic Processes in Fissure Veins. Trans. Am. Inst. Mining Engrs. Vol. XXX, p. 676.

A NEW MATTE SEPARATOR.

By R. R. Hedley, Nelson, B.C.

The problem of most efficiently separating matte from slag in blast furnace work has occupied the attention of metallurgists with results varying very widely.

In copper matte smelting it is more or less simply a question of settling by gravity; while in lead smelting, with base ores, the problem becomes more complex. The day of the conical pot with a tap hole is past, and large rectangular forehearths are used. Many conditions prevail, making it impossible to produce a slag sufficiently free from silver to discard, and in such cases it is customary to save and re-smelt the shells which chill rapidly on the pot and which carry a large proportion of the silver. In copper smelting, Nicholls and James of Swansea recommend a small reverberatory with independent fire-box in which the slag is reheated, and Mr. Rhodes of the Arkansas Valley Works was using a large reverberatory in "97, into which the matte and slag were poured as taken from the blast furnace in slag pots. Many attempts have been made to take the matte direct from the furnace and thus avoid the intermixing with slag, but so far as I know these have not been economically successful.

I propose to describe the device, successfully used for the past six months, in the Lead Smelting Works of the Hall Mining & Smelting Company Ltd. at Nelson, invented and patented by Mr. Henry Harris, A.R.S.M.; and, if possible, to point out concisely and clearly its manifold and manifest advantages. First of all, it is manifest that a fairly complete separation of matte from slag takes place within the furnace where a very high heat is developed, and that if this separation can be maintained without the furnace, a vast advantage is gained over letting both matte and slag flow together to any receptacle where they must be again separated by gravity at a lower heat, or by reheating.

The Herreshoff forehearth has its greatest advantage from the application of this principle, carrying the slag overflow well above the tap hole of the furnace, and periodically tapping matte as it accumulates. In the early 80's, John L. Thomson, Superintendent of the Orford Works of New Jersey, adopted a form of forehearth, now known as the Orford Syphon-tap, whereby on tapping the furnace a constant flow of matte and slag is maintained whilst no attempt is made to maintain the separation existing in the furnace. This is very successfully used for copper smelting where the matte fall is heavy, and I have used it on lead furnaces with satisfaction. This is simply a rectangular settling box with a division wall having an aperture at the bottom through which matte is permitted to flow, and rise in the second compartment, whence it flows at a level slightly lower than that of slag in the first compartment. In lead smelting, with ores such as the metallurgist of to-day is called on to treat, one has not only to contend with the prills or granules of matte, so difficult to separate completely from the slag when both flow intermittently from the furnace, but there is also that agglomeration, hardly matte, which chills so readily, and rapidly builds up the settler, necessitating so frequent change and such labour to break up; and again that elusive zinc sulphide which declines to settle, but floats gaily, carrying its quota of silver into the slag flume.

It was after enlarging our forehearths, using a secondary conical pot, and even a third, improvising an Orford syphon-tap, etc. that Mr. Harris thought out the device now in use and giving excellent satisfaction. It is patented under the name of the Harris Distributor, as it distributes the matte and slag already separated in the furnace. This distributor combines the essential principles of the Herreshoff forehearth and the Orford syphon-tap, improving on the former in that its first compartment is virtually a continuation of the surface of the furnace crucible, having a free flow through an orifice 10 inches long by 5 inches high instead of connected therewith by a small tap hole. I can best describe this apparatus by quoting from Mr. Harris as follows:—

"It consists of an L shaped cast iron box about 30 inches "long, lined with tile or water jacketted to suit conditions which "is placed in free communication with the tap hole of the furnace, "which should be as wide as possible. The walls are deep enough

"to afford a sufficient head to retain the amount of slag and matte "desired in the furnace. Placed in this box at right angles to the "face of the tap jacket is a water jacket partition below which is an "aperture a few inches in height and which serves to laterally "divert the matte. Referring to the sketches,—

"Fig. 1, is merely a diagram showing its manner of operation.

"Fig. 2, is a cross section on the line AA in Fig. 1.

"Fig. 3, shows a plan of the actual apparatus.

"Fig. 4, is a vertical section on the line BB in Fig. 3.

"The manner of operation is as follows:—

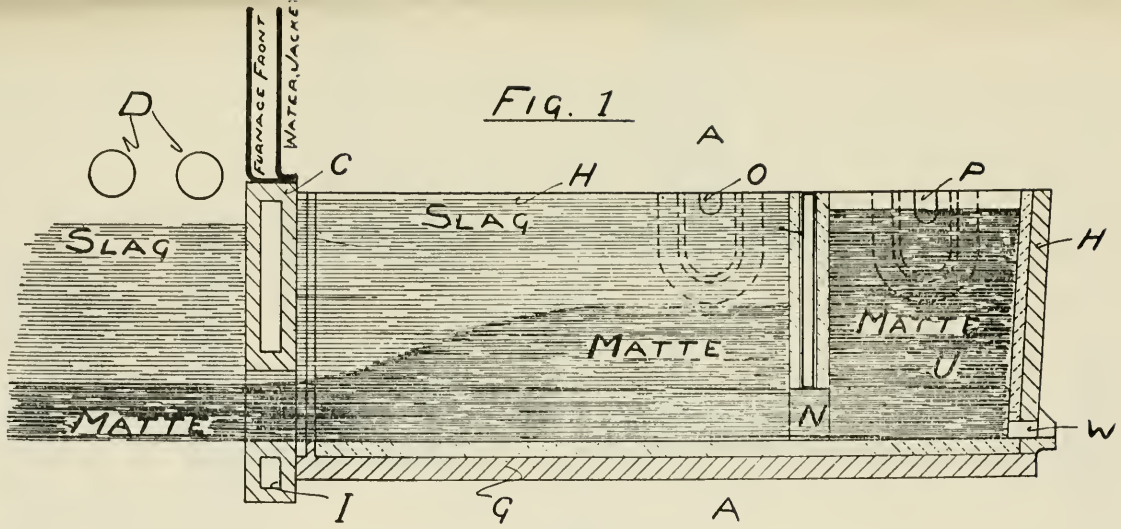
"The apparatus is pressed closely against the tap jacket E "of the furnace, with its bottom on a level with the bottom of the "tap hole F.

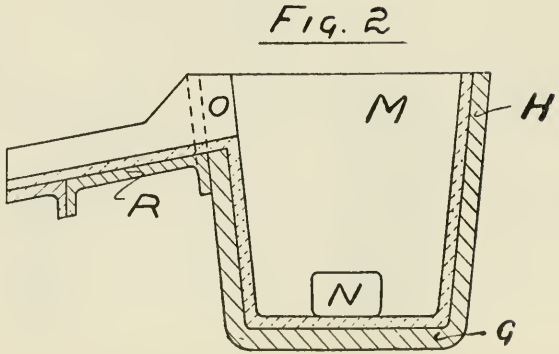
"When the furnace is in full operation the matte and slag "will be maintained within the furnace at levels corresponding to "the head afforded by the height of the slag and matte overflows "O & P.

"The slag from the double stream flowing from the furnace "will be arrested by the water jacket barries M and will be retained "in the first division T to overflow at O, whilst the matte will flow "through the space N into the second division U and rise until its "head balances those of the matte and slag in the first division of "the box or the matte slag and blast pressure in the furnace and "overflow at P. It will thus be seen that the levels of matte and "slag in the furnace will depend upon the weight of blast and the "height of the overflows O & P which may be varied considerably "at the will of the furnaceman.

"Its operation requires but little attention or skill, and it "will run for two or three weeks without change which is quickly "effected, the apparatus being mounted on small wheels which run "on rails on a truck placed at a height corresponding to two short "rails at the furnace.

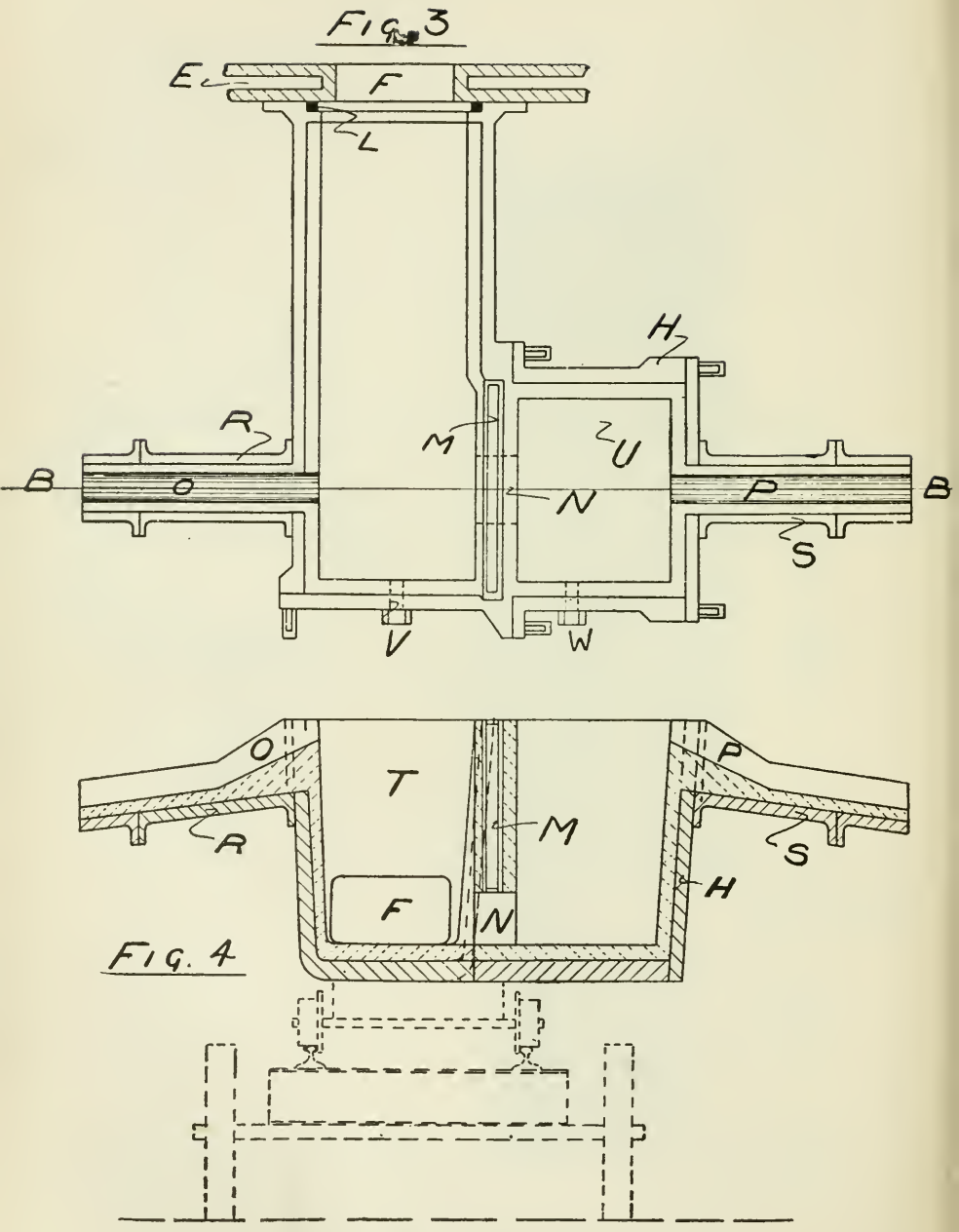
"It is not bolted in any way to the furnace, the only con- "nection necessary being made by tamping a small quantity of fire "clay in the groove L which when filled with slag, which chills "between the surface of the jacket and the flange, makes an ex- "tremely efficient seal under the most stringent conditions.





A NEW MATTE SEPARATOR

FIG. 1—Diagram showing manner of operation. FIG. 2—Cross-section on the line A A FIG. 1.



A NEW MATTE SEPARATOR

FIG. 3—Plan of Apparatus. FIG. 4—Vertical Section on the line B B, FIG. 3.

"The tap hole V is provided to tap out any small quantity of "lead which may accumulate, and also for tapping out the fluid "contents of the furnace when necessary.

"Where the production of matte falls extremely low, the "operator does not attempt a continuous flow of matte for any "length of time but builds up the level of the matte overflow re-"ducing it at regular intervals. The oscillation of the contents of "the box due to the blast, prevents in this design the solidification "of the matte even when it is allowed to stand for a reasonable "time. Should however the matte in the second division U be-"come solidified, it is easily removed without interfering in the "least with operation of the furnace."

Naturally, some time was occupied in perfecting this device and in becoming familiar with its operation, but it is now a recognized adjunct of the furnace, and the advantages gained by its use, in comparison with the discarded cumbersome settlers or forehearths, may be summarized briefly:—a better saving of lead and silver values in slags; a more perfect equilibrium within the furnace, conducing to more perfect metallurgical work and less tendency to irregularities producing troublesome crusts and accretions; less time lost in changing settlers; a saving of labour in handling the same and preparing the contents for resmelting; and a saving in iron and steel tools, as well as matte pots.

MORE NOTES ON STAMP MILL PRACTICE.

By Courtenay de Kalb., New York.

This paper may be considered correlative to one on the same subject published in the Transactions of the Canadian Mining Institute, six years ago, representing more varied experience, confirmatory of some of the opinions then expressed, and destructive of others.

SCREENS.

The unwisdom of depending too much upon the diameter of screen opening to determine size of pulp must be again insisted upon. Height of discharge and quantity of feed water are the best regulators. The diameter of screen opening is never constant, owing to wear, and the difference of every 1,000th of an inch is vital. The skilful batteryman will, with a well-mixed (bedded) ore maintain a uniform product throughout the mill, though conditions of weight of stamps and diameter of screen openings may vary widely in the different batteries. Every mill should be provided with at least three testing screens, one having openings equal to the diameter of the maximum size of grain admissible for the ore under treatment, one having an opening equal to the middle-sized product desired, and the third of the finest accurate screen made, which is No. 150 mesh, or about .0762 millimeter diameter of opening. The product from every battery should be tested at frequent intervals by wet screening. When the pulp on the coarsest screen exceeds a half of one per cent. of the total weight of the sample the battery screen in that battery should be changed, or extraction will suffer. The ratio between the middle-coarse and the middle-fine should be nearly constant and uniform throughout the entire mill, and above all a constant ratio by weight between the total oversize and undersize material from the finest screen must be carefully maintained. These ratios should be made the subject of regular reports on the amalgamator's report-sheet to the manager, the same as the daily assays. They are equally as important,

for, while the latter indicate values, these ratios have a definite and vital relation to the percentage of extraction which may be anticipated. It is a good plan to throw the responsibility for the screening upon the amalgamator, and for drying, weighing and reporting, upon the assayer.

The perfect screen does not yet exist. Die-cut Russia iron still stands unexcelled for most ores. As a screen should, in the author's opinion, be used as far as practicable chiefly to prevent the escape of grains larger than the pre-determined maximuum which can be economically treated, the larger the ratio of open-space to blank metal in the screen the better, and the openings should be so disposed as to facilitate discharge to the utmost. For limiting discharge, regulate height of drop, height of discharge, and quantity of water. The "herringbone" pattern of diagonal-slot die-cut Russia iron screen, has been found, in my experience, to combine in the highest degree this advantage, coupled with good wearing power. The Tyler rolled wire screen gives a better discharging surface, but the crown of the mesh is the thinnest and weakest portion in this screen, instead of being the heaviest, and its life is correspondingly shortened. If this screen can be made with the crowns electrically welded, it will be a great boon to the millman. The tendency of the woven-wire screen to clog does not apply to any serious extent to the rolled wire screen.

FOUNDATIONS.

My personal experience with concrete mortar foundations has led me to regard them with disfavor. The surface must be very smooth. It is unsafe to compensate for unevenness in the set of the concrete against a "form", by grouting, as this gives a bearing surface of uneven density. The tendency of concrete mortar-blocks to wear rapidly and unevenly seems irremediable, and will so remain until some one can devise a lock-nut for foundation bolts insuring absolute rigidity. A rubber cushion directly between the mortar and the concrete is a mistake, and in fact merely invites rapid wear, since the inevitable prominences on the concrete surface compress the rubber at those points inducing excessive wear, so that destruction of the cushion soon ensues. Anvil blocks between the mortar and the concrete block increase

the difficulty of rigidly anchoring the mortar, and exaggerate enormously the evil tendency of the concrete block to induce breakage of stems. Having had opportunity to compare the behavior of batteries mounted on concrete and on built-up wooden blocks in the same mill, crushing identical ore, and this in two different mills in separate districts, I have in each instance found the ratio of broken stems to be as 1 to 3 in favor of built-up wooden blocks. I have been led to adopt as best a rock or concrete bottom, accurately dressed smooth and level to a straight edge in every direction, as a support for a built-up block of 2″ x 10″ creosoted white or sugar pine, spiked together, not less than 12′, nor more that 14′ in height, dressed smooth on top and carrying a $\frac{1}{4}$″ best grade pure Pará gum sheet as a cushion against the mortar. Such blocks are good for 8 to 10 years, even where drainage of block-pits is not good. To reduce the wear of concrete blocks I have employed with marked success a facing of $\frac{1}{4}$″ wrought iron sheet, at least 4″ wider than the width of the mortar base, and 2″ longer. This effectually stops the wear of the sharp edge of the mortar on the concrete if any nuts loosen, and it furnishes a suitable surface for the rubber cushion. This comes very near eliminating the disadvantages of the concrete block, but nuts on foundation bolts will loosen quicker than with wooden blocks, and more stems will break on concrete.

STAMP DUTY.

Stamp duty is relative, depending not only on the character of the ore, but on the rate of discharge which has been found to give the most economical results. The metallurgist who has not advanced to the point of tolerating the low crushing efficiency per H. P. of the stamp mill for the sake of the extraction by amalgamation which he can make it yield, is in error at the very foundation of the trade. If you are not getting your large recovery of gold values inside your batteries, there is something wrong with your methods, or else you ought not to be using a stamp mill, and your whole process needs study and revision. It should be borne in mind that it is not necessarily the mill man who can put through the largest tonnage who is earning the most money. As an example, in a recent experience in California I found

that I could obtain a recovery of 91.5% when crushing 0.121 ton per stamp per hour; and that using the same screen (0.028 in. diam. of opening) but readjusting the mill as to drop, discharge, etc., the duty could be run up to 0.188 ton per stamp-hour, with a reduction of the recovery to 77%.

MORTAR LINERS.

A long and trying experience with mortar-liners has led to my abandonment of this attractive adjunct to a mill. Theoretically it should be possible by the use of liners to have at command an adjustment of the width and depth of the mortar, thus giving that flexibility which would enable it to meet changing characters of ore. Practically I have found that such great inequalities of wear of the mortar are induced by liners that ere long it is impossible to hold them in place, and so far as the bottom-liner is concerned it becomes a sort of teeter-board, and throws the whole line of dies to one or the other end of the mortar, inducing cupping, and destruction of the ends of the mortar shell itself. A good hard gray-iron mortar, with a base 9″ thick, and ends at least 2¼″ thick to a height of 10″ above the mortar-lip, is the best that can be had. In order to quote low prices, manufacturers design mortars with scanty metal on base and sides. Insist on plenty of metal; it costs little, while demurrage of your mill later on may destroy your profit and ruin your chances of success. In general the narrow mortar of moderate depth (say 14″ wide and 6″ deep at the lip) is the most satisfactory, in that it will fit more cases. The chuck blocks will then do the rest.

SHOES AND DIES.

While admitting that no rule may be established for all ores as to the best type of shoe and die, I may set forth as the result of my own practice that I find in the great majority of cases the longest life, highest duty, and most uniform and economical wear, are obtained by shoes and dies made as follows: dies, with one inch thick base, forged steel, made from open-hearth ingots of "80 carbon" (i.e., 0.8% carbon) forged at dark yellow, bases subsequently annealed; shoes, open-hearth "60 carbon" steel, forged at bright

cherry, necks annealed. Shoes and dies made according to these specifications year in and year out have worn respectively until the die was $\frac{3}{4}''$ to $1''$ thick, and the remnant of the shoe was a plaster of steel $\frac{1}{8}''$ to $\frac{1}{16}''$ thick on the end of the boss-head; cupping being so rare as to arouse the gravest suspicions of inattention to duty on the part of the amalgamators. The die should be more highly elastic than the shoe, because the crushing of the ore particles in stamp milling is done as a result of the reaction from the resilient die, the waves of compression transmitted through the particle from the shoe being reflected from the die, and the strains set up by the on-coming and the reflected waves, exceed the elastic limit of the particle, and rupture, to the point even of comminution results. Place two steel bars $\frac{1}{2}''$ thick on a new die, with a $1''$ fairly round ore particle between, and let a newly shod stamp drop on it. You will find a number of irregular fragments of varying sizes, with a small conical pile of ore-powder resting on the die very highly compressed in the center so as to be often adherent to the die. This experiment not unfairly represents what occurs in practice, where the blow delivered upon the protruding larger masses of ore is checked by the expenditure of work in compression of ore particles, until the momentum is overcome by the increasing resistance of the number of uncrushed particles relatively to the remaining kinetic energy of the falling stamp. The crushing of the finer particles, which can never be reached by the stamp, owing to this masking of its blow, is manifestly due to attrition in the mass of pulp, and to minor blows transmitted from the stamp through ore-particles to smaller pieces between these and the die. It is interesting to observe that the percentage of pulp produced in the above experiment, crushing single particles, which will pass through a 0.0762 m.m. opening is roughly 22%, while in ordinary work a mill will produce from 28 to 40% of pulp of this grade.

INSIDE AMALGAMATION.

In some mills the bulk of the amalgam recovered from the batteries is found in the sands; in the Yellow Aster (Cal.) mill, it tends to form hard balls in the corners of the mortar, but this is a rare though not exceptional case. Ordinarily the "catch" is

mainly on the plates. It is always good practice to use a chuck plate, unless it persistently scours to bare copper. What is caught on this plate is so much to the good, and it costs but little to get it. Usually it is a very productive plate, and should yield hard amalgam in ridges, often a half inch high. It is easier to secure good work on the back plate. Scour will occur sometimes, in spite of careful work, due to unavoidable changes in the mineralogical composition of the ore, rendering the pulp either more or less mobile, and either condition may be a pre-disposing cause. The tappets may be re-set to compensate, and regulate the splash to check the scouring, but if plates have begun to catch, and then start to scour, it is safer to remove them at once, substituting new ores, and then readjust to bring the splash back to proper form. It is unsafe to count on re-catching scoured amalgam on the outside plates. The inside amalgam should be hard and dry, and such amalgam breaks up into thin scales and spicules which float most persistently. The regulation of the splash is all-important. Even when, as seen through the screen, the splash appears to be an even oscillation or wave-motion across the mortar, it may in fact be scouring. If the plates show much bare copper it means a loss, for amalgam is certainly forming, and is equally being worn away, much of which is inevitably lost. The inside plates must be coated with amalgam, or else they are a disadvantage. The adjustment of a battery to avoid scour cannot be made in a perfunctory manner, nor can it be done according to rule. It is only in rare cases that every stamp in a battery can be set to the same drop, and good results obtained. After a clean up they must be set that way, with the center stamp having a little higher drop than the others. Then one by one each stamp must be reset until all tendency to scour is overcome. Even then they must be watched, and re-set as the shoes and dies wear, and as the chuck block is dropped, giving a narrower space in which the crushing must be done. If scour is persistent, in spite of such vigilance, it indicates either that the plates are too near or too far from the dies, or that the sands are too mobile ("quick") or too heavy ("dead"). The latter difficulties may be overcome by changing the ore mixtures, which in most mines can be accomplished if enough stoping ground is blocked out. Sometimes a change in the quantity of feed water is all that is necessary.

Another difficulty is the obstinacy of many amalgamators who will not attend to all these details, who expect a mill to run itself, and refuse to be taught better. Such men are too expensive to keep.

CONSTANT ORE MIXTURES.

The bedding of ores, so as to secure proper mixtures, giving the best results in milling is almost as important in amalgamation as in smelting; but as the physical character of the pulp is the important thing, which no analysis can foretell, it will not do to "stock" in the bedding-bins too far in advance of the mill-needs. It is better to have ore of different characters broken and ready in the chutes, to be drawn upon as needed.

DRESSING OUTSIDE PLATES.

The experienced amalgamator will never allow discoloration to begin upon the outside plates. The preventive, as well as the remedy, is hard, brisk rubbing with whisk brooms. Discolored plates indicate laziness, inattention to duty! A dark, crusted deposit, however, indicates antimony, for which there is no effective remedy but to find where the ores carrying it come from, and omit mining those blocks of ore which bring trouble to mill. It is usual to find antimony segregated into chutes or bunches, at least to such an extent that the difficulty may be minimized by intelligent management.

To clean plates borax soap is altogether the best material to use under modern conditions It is sufficiently alkaline to clean off any stray animal fats, and it will emulsify the mineral oils, and leave the plates bright and ready to take mercury or catch-gold. Caustic alkalies no longer have any legitimate place in the amalgamator's stock of supplies. They do not touch the mineral oils, and practically all modern lubricants are petroleum derivatives. Cyanide of potash should never be used under any pretext. It hardens the amalgam, and causes it to scale. If bare copper occurs, from any cause, scour with sand, wash with borax soap, rinse, swab with a solution of mercuric chloride (corrosive sublimate), rinse well, and burnish with a dry cloth. A surface so prepared will promptly start to catching amalgam.

USE OF SALTS WITH COPPERY ORES.

If the ores carry copper sulphides, copper sulphate will usually be present also, or will be formed to some extent in the battery. This may be largely decomposed and the copper amalgamated with the gold, by feeding common salt with the ore. This may be due to the normal reaction between the copper sulphate and the metallic iron in the battery, the salt serving merely to facilitate the reactions and amalgamation by increasing the conductivity of the solution. Further chemical phenomena may be involved, but I have as yet had no opportunity to study the situation critically in the laboratory. This practice is often useful in protecting the future cyanide treatment of the mill sands.

OUTSIDE AMALGAMATION.

The hardness of the amalgam for good work no man can determine in advance for any ore. The right consistency must be found out by actual trial in each mill. Usually a granular, frosty appearance, with a softness such that the fleshy part of the thumb can just make an impression, is most likely to give the best results. Abundant area of copper plate beyond the battery is important. Most mills are deficient in this regard. It pays to have enough. Forty-eight square feet for each battery may be taken as the minimum and beyond this use as much as pays. There is no advantage in using copper plates plated with more than 1 oz. silver per sq. ft. In fact, more than this is a positive disadvantage. A good amalgamator can build up amalgam on raw copper without difficulty, and keep his plates bright and fresh. The chief advantage in silver plating is to reduce the absorption of gold by the plate. A first dressing on bare copper with dilute silver amalgam will yield a surface more sensitive as an amalgam-catcher than a silver-plated copper plate.

The foregoing statements have been made with the positiveness of conviction resulting from successes in practice wrung out of trying situations, but with no thought that the final word has been uttered, and the author hopes to stimulate criticism and call forth new confessions of experience, to the betterment of his own and others' metallurgical methods.

RARE EARTHS IN PEGMATITE VEINS.

By J. Obalski, Quebec.

Until recently the ores of rare metals such as Thorium and others were considered only as mineralogical curiosities but of no industrial value. Now there are uses for those metals which are in good demand and these notes are intended to call attention to some minerals which have been found in pegmatite veins of our Laurentian formation and which have not hitherto been even considered as by-products.

In the Villeneuve Mica mine on the Lievre river uraninite and monazite have been mentioned and an analysis of the uraninite has been published in the reports of the U.S. Geological Survey and reproduced in my report of 1901 on mica.

This specimen contains 37% of uranium oxyde, 6% of thorium oxyde besides oxydes of cerium lanthanum, yttrium in smaller proportions.

The Maisonneuve mica mine in Berthier County contains the mineral samarskite which has been analysed by Dr. Chas. Hoffman of the Ottawa Geological Survey. It contains 55% of colombic and tantalic acids, 14% of yttrium oxyde, 10% of uranium oxyde, 4% of cerium oxyde with very little tin. Last year a company was organized for the working of this mine and it seems that the company has especially in view the production of this samarskite. This mineral appears to be more abundant than at first supposed and probably other minerals will be found there. Mr. H. Nagant of Quebec, who is making a special study of those rare earths, has found amongst the specimens, from this mine a mineral which contains a higher percentage of tin which was indentified as *Fergusonite*. The same company has also purchased the Mine of Pied des Monts near Murray Bay which contains the mineral cleveite in which the author discovered radium a few years ago. He also found in the same mine specimens of bituminous coal containing a large propor-

tion of uranium. Last summer, in the township of Taché, near Lake St. John a mica mine was opened up and amongst the specimens brought to the author's office were identified, with the aid of Mr. Nagant, the minerals *orthite* or *allanite*, and *goldolinite*. In the first Mr. Nagent has found 2 per cent. of tin and specks of native *bismuth*.

In these various mines these minerals have been found by accident and probably, if other mines were visited by mineralogists, there would be some chance of discovering more or other varieties, as ordinary miners are not able to identify all the heavy stuff which is mixed with the rock.

ON THE NEED OF A TOPOGRAPHICAL SURVEY OF THE DOMINION OF CANADA, PARTICULARLY WITH REFERENCE TO THE DEVELOPMENT OF THE ECONOMIC RESOURCES OF THE DOMINION.

By Frank D. Adams, Ph.D., McGill University, Montreal.

At no time in its past history has Canada shown such a rapid growth and development as during the last half dozen years. Settlers are pouring in and new districts are being opened up in all directions, and yet the Dominion is without that great national asset which is a prime necessity for the satisfactory and economical development of our natural resources—a topographical map of our country. Canada is in this respect outstripped by every civilized country in the world. We are, in fact, like a householder who is engaged in furnishing his house and yet has no adequate knowledge of the number and dimensions of its rooms, and only a most hazy idea of the size and character of the grounds surrounding it.

The proof that the people of every other civilized country regard such a survey as necessary, is shown by the fact that they have long since, in every case, established a regular ordinance or other government survey, which has prepared and published topographical maps of these respective countries, and if we consider for a moment the uses of such a map and the great waste of public and private moneys which would be avoided by its preparation, it will at once be seen that the construction of a good topographical map of Canada is one of the most pressing needs of the Dominion at the present time and one which will make itself felt with ever increasing insistence as the country opens up during the next few years. The preparation of such a topographical map of the Dominion would be a public work of enormously greater value than many other pieces of work which are now being undertaken by the government and would cost much

less. It would at the same time be an undertaking which would provide a permanent asset for the country and one which would pay a high rate of interest on the original expenditure, in the services which it would render in a thousand ways both to our Government and to the citizens of the Dominion. The singular fact is that Canada is surveying her country incessantly, and yet has no good map of it. Whenever a new project comes up, the land is re-surveyed. If a railway is planned, almost the whole work of examination of the country must be done from the start. If an engineer wishes to ascertain with precision how much electric energy can be derived from the waters of any river, it is necessary for him to go and make a map of the river basin as well as to gauge the stream. In 1903 one portion of the Grand Trunk Pacific controversy would have been avoided if there had existed a proper map of northern New Brunswick. Expert opinion at that time tended to the belief that the shape of the hills in that part of the Dominion would render it very difficult to obtain low grades across them. A map such as the United States map of the Adirondacks would have settled the question at once and have shown that the danger was imaginary.

Furthermore, we have a dozen or more different branches of the Government's service carrying on isolated and independent surveys, often covering the same areas, all more or less imperfect and by their duplication entailing a great loss of time and money. Thus, in the North West Territories, within a comparatively limited district, surveys have been made by the following branches: Topographical Surveys and Timber & Mines branches of the Department of the Interior; Geological Survey; Department of Railways; Indian Department; &c. In the older provinces this state of affairs is further complicated by the existence of surveys under Provincial Government auspices, surveys by the Public Works Department and by railway companies, charts of the coast by the Department of Marine and the Admiralty, and other minor surveys which it is not necessary to enumerate.

The remedy for this state of affairs is admirably outlined in the recommendation of the Civil Service Commission of 1882 as follows:—

"Your Commissioners find that maps for various purposes are prepared in several Departments and, by the evidence pro-

duced, it is shown that differences frequently occur in maps of the same district when issued by more than one Department. To prevent this and to promote accuracy and security, it is recommended that a special cartographic branch be created and that the duty of this branch of the public service should be to issue reliable maps of the various parts of the Dominion."

Now, what is the nature of a good topographical map such as that which we need for the proper development of our varied resources, and what will it show? It will show accurately, in the first place, the position of every natural feature in the district surveyed. In the second place, it will show with equal accuracy the relief (height, slope, &c.) of every part of the area in question, and, thirdly, it will also show the varied results of the human occupation of the country—towns, villages, roads, &c., &c. The precise character of such a map will be more clearly seen if we consider the case of the excellent series of topographical maps which are now being issued by the Geological Survey of that country whose conditions most nearly approach to those of our own, namely, the United States.

The features exhibited on the topographical maps of the United States Geological Survey are:*

1. Hydrography, or water features, as ponds, streams, lakes, swamps, &c., which are printed in blue.

2. Hypsography, or relief of surface, as hills, valleys, and plains, which are printed in brown.

3. Culture, or features constructed by man, as cities, roads, villages, and the names and boundaries, which are printed in black.

This combination of colors renders these topographic maps readily legible. On the reverse of each sheet is a description of the mode of reading the map, and a legend, or series of conventional signs, indicating how the various facts shown on the map are represented. All these conventions are self-explanatory and are readily understood and interpreted by the layman, except, perhaps, the brown "contour" lines.

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* See "The United States Geological Survey"—Bulletin No. 227 U.S. Geol. Survey, Washington, 1904, p. 57. The author also desires to acknowledge his indebtedness to James White, C.E., Dominion Geographer, for information employed in preparing the present paper.

These contours are lines of equal elevation—lines along which the ground would be touched by the border of a water surface (of the ocean, for instance) if it were repeatedly raised by a given amount. Contour lines express three features of relief —(1) elevation, (2) horizontal form, and (3) grade or slope.

The topographic maps of the United States Geological Survey represent, beside the natural features mentioned, such artificial features as are of a public or more enduring nature, as state, county, township, and city boundary lines; reservation, land-grant, and public-land township lines; railways, streets, roads and paths; bridges, ferries, dams, locks and wharves; the location of permanent bench marks and triangulation stations, and the positions of light-ships and light-houses, mines, shafts and tunnels. The only private features shown are houses, factories, stores, etc., no barns or outbuildings being represented.

As the outlines of wooded areas are to be indicated on these maps, National and State foresters find them invaluable as a base for classifying the woodlands and recording the nature and quantity of the various trees and the relations of the wooded areas to highways of transportation, as railways, streams, &c. These maps are, of course, essential to detailed geological studies and to investigations concerning mineral resources, water power, and land reclamation.

A good topographic map renders unnecessary a special survey for each new need. Prior to the existence of such maps every city was obliged to expend large sums in water-supply surveys. At far less cost the topographic map shows not only all these important local features, but also the relations between the artificial features in the immediate neighborhood and the topography and culture of the surrounding country, and thus broadens the scope of every such investigation.

It is noteworthy, that with the exception of one map of a portion of Manitoba and a few of portions of British Columbia and the Yukon District, none of the maps hitherto issued by the Canadian Government show that most important feature of a topographical map, the relief of the surface.

The advantages of an accurate topographical map of our country might be set forth as follows:

(1) Educational—(a) By promoting an exact knowledge of the country; (b) by serving teachers and pupils in geographical studies.

(2) Practical—As preliminary maps for planning engineering projects. Highways, electric roads, railroads, aqueducts and sewerage plants may be laid out on them, and the cost of preliminary surveys may be saved. Areas of catchment for water supply, sites for reservoirs, and routes of canals may be ascertained from these maps.

(3) Political—In all questions relating to political or legislative matters. For these purposes they afford accurate information as to the relation of boundaries and towns to natural features.

(4) Administrative and Military—In all questions relating to Federal or State administration of public works, as canals, reservations, parks, highways, postal service, and as military base maps on which to plan works of offence, defence, camps, marches, &c.

(5) Statistical—As base maps for the graphic representation of all facts relating to population, industries, products or other statistical information.

(6) Economic—As a means for showing the location, extent, and accessibility of lands, waters, forests, and valuable minerals. In this respect these maps are indispensable to State and Federal bureaus, and to owners, investors and corporations.

A specific case of the saving effected by the use of such a topographical map is given by President C. R. Van Hise:—

"A railroad company owned two lines in northern Michigan and Wisconsin which they wished to connect by a branch some forty miles in length. The country was unknown between the two lines. Under my direction topographical, geological and timber maps were made of about twelve hundred square miles, at a cost of about $25,000. After these maps were made the line was laid down in the office with a beautiful grade, and with the best location possible with reference to iron ore and timber. One of the features of the line was that it crossed a bold trap range which was supposed to be impossible to cross except at great expense, by finding gaps through it. This line crossed the branch of another railroad about twelve miles long, which

because it went around the end of this trap range, when the gap was directly in front of it, was at least two miles longer than necessary. These additional two miles of road cost fully as much as the entire survey of the twelve hundred square miles.

It is my profound conviction, if topographical surveys were made of broad zones where it is expected to project railroads through rough forested country, that many times the cost of the survey would be saved in the construction of the railroads, besides getting a better location both as to resources and to grade than is possible by the random methods employed at the present time for the locating of railroads in rough forested country."

The construction of a topographical map of the United States has been assigned to, and is being admirably carried out by, the Geological Survey of that country; the Coast and Geodetic Survey confining their operations to the mapping of the coastline and the strip of country bordering it.

The general plan adopted for mapping the United States consists in dividing the country into quadrilateral areas (called "quadrangles") bounded by parallels and meridians of latitude and longitude* Three regular scales and a series of special scales have been adopted. For reconnaissance maps in the rougher portions of the Far West and Alaska the scale of 1:250000, or nearly 4 miles to the inch, is standard. For the general map of the United States the scale of 125,000, or nearly 2 miles to the inch, is standard. In the more densely populated districts—the Atlantic coast, parts of the Central region, and portions of the Pacific coast—the scale of 1:62500, or about 1 mile to the inch, is standard. These scales are readily convertible into the metric and other systems understood in foreign countries. However, at the bottom of each sheet the scale is expressed in three ways—by a graduated line representing miles and parts of miles in English inches; by a similar line indicating distance in the metric system, and by a fraction. Special larger scales, from 2,000 feet to the inch up to 100 feet to the inch, are used for detailed surveys of important mining regions, for the planning and construction of irrigation projects, etc.

* See Bulletin 227, U.S. Geol. Survey, already cited, pp. 60–63.

The maps are printed on sheets approximately 13 by 17 inches. The area represented on a sheet on the 1 mile scale is 15 minutes of latitude and of longitude, or, on the average, about 225 square miles; on the 2-mile scale, 30 minutes of latitude and of longitude, or about 1,000 square miles; and on the reconnaissance or 4-mile scale, 1 degree of latitude and of longitude, or approximately 4,000 square miles. An atlas sheet is known by the name of the most important town, city or natural feature within the quadrangle represented.

The methods of field work followed in making these topographic surveys are as follows: At rather distant intervals through the territory under survey, say 10 to 25 miles, monuments are established, the positions of which are accurately determined by trigonometric methods and recorded in degrees of latitude and longitude. For this purpose base lines from 4 to 6 miles in length are measured with great accuracy, the location of one end of each base and of its azimuth being determined astronomically. From this base a net work of triangulation is expanded to hilltops, mountain summits and other prominent objects, the positions of which are carefully determined by computation. This is the special work of the section of triangulation and computing. All existing triangulation by other organizations is utilized. Where the nature of the country renders the extension of triangulation impracticable, primary control is extended by means of careful lines of traverse.

The resultant positions are plotted accurately, by latitude and longitude, on large sheets of drawing paper, approximately 18 by 24 inches in size, called plane-table sheets. To each topographer is assigned, as his season's work, the mapping of one or more quadrangles, and he enters the field equipped with the plane-table sheet, which has on it only the trigonometric positions. A field party usually consists, in addition to the topographer in charge, of one skilled assistant, of the grade of assistant topographer or topographic aid, and several surveyors temporarily employed as traversemen or levelmen, with the necessary rodmen, teamsters, cooks, and other camp hands where subsistence is by camping.

The levelmen proceed to run lines of spirit levels over the various roads and paths, to determine elevations. The higher

order of primary leveling, elsewhere described, is run at such distances apart that at least two permanent bench marks may be established in each township or equivalent area 6 miles square. Levels of a less degree of accuracy are then run over every road, and where these are too far apart, say a mile or more, the levels are run over trails or across country, either by spirit level or by vertical angulation with stadia.

Meantime the topographer is extending a graphic triangulation on his plane-table board, the object of which is to locate precisely, on his sheet, points all over the area under survey. These include signals placed upon prominent hills, church spires, lone trees, and other definite objects; or in case the country is of such nature that it cannot be controlled by triangulation, he has careful lines of traverse, by stadia or steel tape, run at intervals of about 5 miles and connected with the lines of primary traverse previously run across the sheet. At the same time, the traversemen, equipped with lighter plane-table boards on which are smaller sheets representing about one-fourth of the whole quadrangle, are running graphic traverse lines over all roads and paths and across country, with a view to locating the cultural features, the courses of streams, the outlines of lakes, etc. On highways the distances are measured by counting the revolutions of a wheel, the circumference of which is known, or by stadia, and in dense woods by tape.

On the completion of this primary control and coincident with its preparation the topographer transfers to a clean sketch sheet the primary control points and adjusts to these the positions determined by secondary plane-table triangulation or stadia or tape traverse. The less accurate traverse lines are then adjusted between these more accurate positions and the elevations procured by spirit leveling or vertical triangulation are then added to the map.

Equipped with this control sheet, on which are shown approximately one trigonometric location per square inch of paper, two or three linear inches of traverse per square inch of paper, and from two to ten elevations per square inch of paper, the topographer walks or rides over all roads and paths and about the margins of lakes, across country, etc., selecting routes so near one another that he may be able to see all portions of the land. If

the country is rough he uses an aneroid, setting it at one of the fixed elevations and frequently checking it by others of like kind; with it he is able to determine the crossing of each contour line on his route of travel. In a relatively flat country he uses a hand level, or reads vertical angles from his plane-table and ascertains like facts. Stopping frequently, he sketches in, by means of contour lines, the relief of the country, and corrects as he goes the positions of roads, houses, streams, etc., located by his assistants.

At the close of the field season the temporary employees are discharged and the party chief returns to the office. Here, during the winter season, he completes with great care the drafting of the maps, using the three colored inks selected as standard for this work—black for culture, blue for drainage, and brown for relief. Town and county maps are consulted, correspondence is entered into with postmasters and other local officials and railroad corporations, all compiled material is carefully scrutinized, and the final outlining of political boundaries and the lettering of names are completed.

These original drawings, as they are called, are at once copied by photography or photolithography, so that they may be available for immediate consultation by the public, pending their engraving on copper for final publication.

The cost of the surveys first made, on the scale of 4 miles to the inch, averaged $1.75 a square mile. Those made a few years later, on the scale of about 2 miles to the inch, averaged in cost $4 a square mile, while those made on the scale of approximately 1 mile to the inch, averaged in cost $10 a square mile. During the field season of 1884 a single party mapped over 11,000 square miles. A few years later the output of a single party, on the scale of 2 miles to the inch, was about 3,000 square miles in a season. Today the more refined and detailed maps, on the scale of about 2 miles to the inch, with a contour interval of 100 feet, cost from $7 to $11 a square mile, according to the country, and a single party can rarely map over 600 to 1,000 square miles in a season. On the scale of 1 mile to the inch, a party now maps rarely more than 500 square miles in a season, and the cost of this work varies between $12 and $30 a square mile, according to the nature of the country.

Being in this Institute more particularly interested in the

development of the mineral industries of our country, we may ask how this topographical work directly aids the miner. This is easily answered. While the topographical branch of the U. S. Geological Survey is carrying forward the topographical survey of the country, parties being at work in almost every state, the geological branch of the Survey is at work making detailed geological maps of special mining areas. So much is this work appreciated in the United States that it is a regular custom when deposits of valuable minerals are found in any district to at once apply to the Director of the United States Geological Survey, for the construction of a geological map of the area or mining camp in question. Thereupon the Director of the Survey fixes the boundaries of the area to be surveyed and constitutes it a "quadrangle," naming it after some town or village within the area. This quadrangle is bounded by proper north and south and east and west lines, and thus forms a sheet of the geological map of America which is now in course of construction. This having been done, a topographical party at once makes a topographical map of the area on the required scale, and this map, without waiting for the edition to go to press, is given in manuscript form to the geologist and is used by him as the basis of his work in constructing a geological map of the area. In fact, no less than four maps of the area are constructed; one showing the topography of the area; another showing accurately the geology of the area and the position of mineral deposits within it if these exist; while a third is so colored as to emphasize the mineral deposits or any bands or occurrences of rock which are likely to contain them, thus serving as an excellent basis for the work of prospectors. A fourth map shows the structure of the area by presenting a series of transverse sections through it. These four maps are bound together in a stout paper cover and constitute what is known as a "folio." By the aid of the contoured topographical map, all surface workings of the camp can be carried out in the most economical manner, the best location for all railways, &c., can be determined, and the general surface development of the area also worked out was to secure the greatest efficiency at the lowest cost. In the geologically colored sheet the distribution and relative position of the various strata, &c., underlying the area, as well as the outcrops of the mineral deposits,

are shown, and from it can be determined the best location for shafts, inclines, drifts, &c., and by it the general development of the underground work can be greatly assisted. Every folio is also accompanied by a sheet of text, which gives a condensed description of the geology of the area in question, written in plain language so that it can be easily understood, while on the inner surface of the cover of the folio there is a brief explanatory treatise of a very general character, and which is identical in all the folios, setting forth the chief geological and topographical terms and explaining the nature of the commoner geological structures. These folios have been found by the mining community of the United States to be of the greatest practical value in the development of the various mining camps, and they have probably done more than anything else to commend the Survey to the mining community of the country.

Such folios would be of inestimable value in the development of the various Canadian mining camps, such as Rossland, those of the Boundary district, or our most recently discovered mineral district about Cobalt, and would commend themselves to Canadians, as those of the American mining camps have to the mining community of the United States. Instead of carrying out such work as this, the Canadian usage has been to send out some unfortunate geologist, with an inexperienced assistant, and to call on him to make a geological map of some complicated area without any topographical basis on which to plot his work. He is then required to furnish a report upon the area, accompanied by a geological map, at once. Such a map however, if it is to be of any value, can only be constructed very slowly, seeing that the geologist is called upon to do, not only his own share of this work but to make a topographical map of the area as well. The geologist, who commands a relatively high salary is thus obliged to spend about three-quarters of the time at his disposal in doing topographical work, which is necessarily of an indifferent quality, and thus has comparatively little time left in a season to devote to that work which properly belongs to his profession and for which he was sent into the field. Such a system can never give satisfactory results, either to the mining community or to the geologist, for it gives the former but little aid and brings discredit on the latter. In the remote and comparatively unexplored

regions of northern Canada, where geological work is necessarily of the nature of a reconnaissance, the geological exploration may be carried on at the same time as a rough topographical map is being produced. But in mining areas very different methods must be employed.

There are very few ways in which the Government could render aid to the development of the Dominion more certainly and more wisely than by the organization of a proper topographical survey, and the most convincing evidence of the appreciation which is extended to such work, by people engaged in every species of enterprise which has to do with the development of the resources of a country, can be had by the perusal of Document 136 of the 57th Congress of the United States, entitled "Abstract of Reports, Letters, Clippings, Endorsements, Resolutions, Petitions and Requests, showing the demand for the Topographical Work of the United States Geological Survey," which was published in Washington in the year 1902. This document comprises sixty-two pages of closely printed text, and consists of letters of commendation from all parts of the country, and requests for the construction of topographical maps of special areas by the United States Geological Survey, in order that such maps may be used for the practical development of the resources of the said areas in one direction or another.

The work of surveying Canada when once done would be a permanent asset to the Dominion, and until such a survey is carried out an enormous amount of duplication of effort and waste of money will take place, all of which could be saved by the construction once for all of a proper topographical map of at least the more settled portions of the country.

In concluding, the words of the Hon. C. D. Walcott, Director of the United States Geological Survey, in a letter recently received, may be quoted: "Such maps are an essential to the proper development of all of the resources of a State. We have reached the point where officials of railroads, of trolley lines, those interested in highway improvements and in the development of city water supplies and sanitary measures, as in general engineering work, do not think of spending one dollar on field surveys until they have first procured from this office the topographic maps and the records of levels run in connection there-

with. We are in daily receipt of testimonials showing the sums of money and the time saved in connection with all preliminary and also of some location surveys for such enterprises. Above all, however, is the topographic map an essential to the study, along modern lines and by best methods, of the mineral researches of a region. The old descriptive methods of discussing the geology of a district have been long abandoned in this country. It has been found that every dollar expended in preparing a mathemat cally correct base map upon which to map the geologic formations for strike and dip and from which to construct structural sections, is returned manyfold in the value and accuracy of the resulting studies of the geologic formations and their economic possibilities. A good topographic map is just as essential a framework upon which to reproduce a facsimile of the underlying geology, as is the steel frame which modern architects use to form and support a masonry building of modern design."

It is greatly to be desired that the Government of Canada should take steps in the immediate future to provide for the Dominion, that basis for sound industrial development, a good Topographical Map.

ON THE ADVISABILITY OF THE ESTABLISHMENT OF A FEDERAL DEPARTMENT OF MINES.

By H. Mortimer Lamb, Montreal, Que.

HISTORY OF THE GEOLOGICAL SURVEY OF CANADA IN ITS RELATION TO THE MINING INDUSTRY.

So long ago as 1832 a petition praying for the establishment and maintenance of a Geological Survey of old Canada, was presented to the House of Assembly. But although the recommendation received the endorsement of Sir John Colborne, then Lieutenant Governor of Upper Canada, it was not even considered by the Legislative Committee to which the matter was referred. Subsequent petitions met the same fate; until in 1841, the united parliaments, under the administration of Lord Sydenham, voted the sum of £1,500 sterling for survey purposes. In this year, Sir William E. Logan, (then Mr. Logan), who was born in the City of Montreal in the year 1798 and had already won for himself a considerable reputation in Great Britain, for his admirable geological work in South Wales, and his important discovery whereby the question of the origin of coal was established in favor of the theory of growth *in situ*, came to Canada on a visit to his brother residing in Montreal, and impressed doubtless with the great opportunities so new and vast a country offered for original research, signified in a letter written at this time his intention, "provided he could make the necessary business arrangements", of offering himself as a candidate to undertake the geological survey of Canada; "*and," he wrote," if I once begin

*Life of Sir William E. Logan—by B. J. Harrington, p. III (Montreal : Dawson Bros., 1883.)

it will not be my fault if it does not go ahead." Lord Sydenham while riding near Kingston was thrown from his horse and died from the injuries which he sustained. He was succeeded by Sir Charles Bagot, who after referring the matter of the appointment of a geologist to Lord Stanley, then Secretary of State for the Colonies, offered the position, on the strong recommendations of such distinguished British scientists as De la Beche, Murchison, Sedgewick and Buckland, to Logan in the spring of 1842, and in August of the same year he entered upon his duties, but for several months his services were gratuitously performed. The actual institution of the survey may then be said to date from the 1st of May, 1843. Mr. Logan's first assistant was Mr Alexander Murray, (afterwards C.M.G., who subsequently became Director of the Survey of Newfoundland). It may here be noted that from the beginning, great stress was laid on the advantage likely to accrue in the direction of mineral development in Canada as a result of systematised geological investigation. This was in fact, the chief argument advanced by the petitioners to Parliament urging the establishment of the Survey; it was the view taken by Lord Sydenham in his support of the measure; and Logan himself as is evident from the opinions expressed both in his published letters and in his official reports, and equally so by his years of useful work, never ceased to regard this as the paramount aim and object of his endeavors. Thus in a letter addressed to Sir Henry De la Beche, in 1843, he wrote, "The main object of the investigation is no doubt to determine the mineral riches of the colony," and again in his evidence before the Parliamentary Committee on the Geological Survey in 1855, he said "The object of the survey is to ascertain the mineral resources of the country, and this is kept steadily in view. Whatever new scientific facts have resulted from it, have come out in the course of what I conceive to be economic researches carried on in a scientific way. . . . . .My whole connection with geology is of a practical character." In short, as is somewhere stated, Sir William Logan belonged to that school of geologists whose motto is "Facts, then theories." And the reports for which he was responsible attest the accuracy of this claim. For example, in the "Report of Progress of the Geological Survey from its commencement to

1863," over one-fifth of the volume, or close on two hundred pages, is devoted to economic geology, specific information being here given in respect to mineral occurrence, location and utilization; while in general the various reports contained in this volume are characterized by the amount of practical information afforded. In 1844 Mr. Logan established in the "Upper Chamber" of his brother's warehouse in Montreal a museum in which to display the large quantities of organic remains and minerals collected by himself and Mr. Murray, during their summer explorations; and still bearing in mind economic requirements, he employed, at his own pecuniary risk, a chemist to make the necessary analyses of mineral specimens.

It was not until the following year, Logan having meanwhile drawn heavily on his own resources for the expenses of the work, that, thanks to Lord Metcalfe, the Survey was placed on a better footing, the employment of a chemist was authorized and the grant increased, covering a period of four years, to £2,000 per annum. But even under these improved conditions the difficulties of carrying on the work efficiently were enormous, not only by reason of financial disabilities but on account of the physical obstacles to be overcome. The greater portion of the country was, of course, a *terra incognita*, so that the geologists were obliged to devote the major part of their time in the field to topographical observations. In another of his long and interesting letters to his friend, De la Beche, Logan wrote: "I wish I could let you see the map of our journey across from the St. Lawrence to Bay Chaleur. The length of our winding line is 111 miles, in which we dialled the twists and turns of two rivers, one thirty-five miles and the other sixty-five miles, obtaining the bearings of the reaches by prismatic compass and the distances by Rochon's micrometer, and registering at the same time the quality, contents and attitude of every bed of rock we saw, with barometric heights, etc. The distance between the rivers we triangulated by means of well marked peaks. I think you would say we deserve some credit for it." In later years, he also refers to the time occupied in work of this character. "It will be easily understood," he remarks, "that this geographical work must unavoidably impede the rapidity of geological examination; and the necessity of so much measurement to fix the position of rock exposures. forces

us, in order to make even a moderate progress, to examine fewer of them, or to give to each a shorter time than we would like, and thus, perhaps, to overlook some of its characteristics." This point was well emphasized by Prof. Agassiz in his evidence before the select committee above referred to, in which after speaking of the inadequate means placed at the disposal of the geologists, he says, "Topographical surveys, to be satisfactory ought to be founded upon astronomical observations, but who would therefore expect that astronomers should leave their telescopes, go into field, chart in hand, and draw maps. Mining operations bear to geology the same relations, that geodetic operations bear to astronomy. All that may be fairly expected of a geologist, is to prepare a geological map of the province he surveys, and thus obtain the information, without which the mineral resources of a country cannot be satisfactorily ascertained."

At the close of the year 1846 Dr. (then Mr.) Sterry Hunt, who subsequently did so much useful work in connection with the survey in Canada, was appointed to the staff, replacing Mr. De Rottermond, as chemist and mineralogist.

Meanwhile the Provincial Act, passed in 1845, had made provision for the continuation of the Geological Survey for five years only, and the time was drawing to a close. However, not without a delay that interfered considerably with the work of the Survey, the act was finally renewed with the same provisions. In the same year the Government decided to send a collection of Canadian economic minerals to the first of the great International Exhibitions in London, inaugurated by Prince Albert. This collection was prepared and placed in the charge of Mr. Logan, who by-the-way during his stay in London, was called upon to defray his own expenses. The exhibit, which obtained a medal, came in for a great deal of notice and praise, the *Times* referring to it as the most interesting and the most complete of all the collections sent from the British Colonies. While in London, Logan was elected a Fellow of the Royal Society. Up to this time actual geological investigations and examinations had been conducted in the mineral bearing districts of Lake Superior, Lake Huron, their coasts and islands; the Huron-Erie Peninsula; the Ottawa river valley; the Eastern Townships from the Richelieu to the Chaudière; in the St. Lawrence valley,

the Island of Anticosti; the Gaspe Peninsula; the north shore of the St. Lawrence for a considerable distance east and west from Montreal, and the country between Lake Simcoe and Kingston. By way of contrast it may be noted that whereas in 1857 geological work in Canada—a country then comprising 331,280 square miles—was being undertaken by a staff of two geologists and a chemist, in the State of New York, whose area is about 46,200 square miles, a geological staff was employed including four geologists, four assistant geologists and a palæontologist; with an annual grant of £2,000 as against one of $20,000, exclusive of the cost of publications.

In 1854, in consequence of a popular demand that steps should be taken to give a wider circulation to the valuable reports and publications of the Survey and thus make them more generally accessible to the public, a select committee on the Geological Survey was appointed by the Government. The evidence before this committee of Messrs. Logan and Hunt, and of other distinguished witnesses, namely, Prof. James Hall, of the New York Survey; Prof. E. J. Chapman, of University College, Toronto; Mr. Alexander Russell, of the Department of Crown Lands; the Rev. Andrew Bell, of L'Original; Prof. Horan, of Quebec, and of Prof. Agassiz, makes very interesting reading and was of a highly complimentary character, but referred to the difficulties under which the survey was working.

Notwithstanding the generally favorable impression which Logan and his work had made upon the people of Canada, there must have been some who were still skeptical as to the advantages which the country would derive from the Geological Survey. The Committee, therefore, did not fail to interrogate Logan closely on this subject. "Can you," they asked, "give any illustration of the manner in which a sound scientific basis leads to practical economical results?" and again, " Have you in your survey as your principal object the establishment of new scientific facts, or has your attention been directed to discovery and pointing out economic advantages?" From Logan's answers to these questions we make the following extracts.

"The object of the survey is to ascertain the mineral resources of the country and this is kept steadily in view. Whatever new scientific facts have resulted from it have come out in the course

of what I conceive to be economic researches carried on in a scientific way. . . . . Thus economics lead to science and science to economics. The physical structure of the area examined is, of course, especially attended to, as it is by means of it that the range or distribution of useful materials, both discovered and to be discovered, can be made intelligible. A strict attention to fossils is essential in ascertaining the physical structure. . . . I do not describe fossils, but I use them. They are geological friends who direct me in the way to what is valuable. One of them who is not yet specifically baptized, helped us last year to trace out upwards of fifty miles of hydraulic limestone. . . . My whole connection with geology is of a practical character. I am by profession a miner and a metallurgist. A due regard to my own interests forced me into the practice of geology, and it was more particularly to the economic bearings of the science that my attention was devoted."

After hearing the evidence, the committee made the following recommendations:

(1) Republication of a revised edition of not less than 20,000 copies of the reports, with a coloured map.

(2) Publication of the same number of annual reports in future years.

(3) The periodical publication of 3,000 copies of plates and descriptions of fossils, etc.

(4) Gratuitous distribution of reports in certain directions and the remainder to be sold at cost price.

(5) Establishment and maintenance of the museum and library upon an efficient footing.

(6) To provide for the supply of geological and mineralogical specimens to other museums.

(7) The employment of topographical surveyors and their parties to assist in the geological surveys, when judged necessary.

(8) The employment of two or three additional explorers.

(9) The employment of a resident assistant, as keeper of the museum, and in the general business of the office.

(10) The employment of a second assistant geologist, charged more especially with the exploration of mineral localities. (But to this the rider is added: "The committee wish it to be understood that in the present state of the country they consider this

the least essential addition to the establishment, and unless ample funds are provided, they would not advise it, to the prejudice of any other of their recommendations.")

(11) The encouragement of voluntary assistance by the publication of questions and short instructions how and what to observe and collect.

(12) Securing the aid of deputy provincial surveyors, and requiring candidates in the future to pass an examination in the rudiments of geology.

(13) The establishment of certain points in different parts of the country, as a basis from which local surveys may be reckoned.

(14) Requiring railway companies to furnish plans and sections of their surveys.

Accompanying these recommendations an estimate was furnished, in which the annual cost of the Department was placed at £6,000.

At the Paris Exhibition of 1855 Canada's collection of minerals, in the charge of Messrs. Logan and Hunt, was very highly commended, and for his services in this regard Logan was awarded a gold medal and presented by the French Emperor with the cross of the Legion of Honour, and in the following year, Her Majesty conferred on him the honour of Knighthood, and the Geological Society bestowed on him the Wollaston Medal, as a sign of their appreciation of his work. On his return to Canada the Geological Act of 1850 had expired, and doubtless apart from the findings of the select committees, the honour shown to Sir William while abroad and the influence he personally exerted upon his return, was to no small degree responsible for the renewal of the Act for a further term of five years and the increase of the annual grant to £5,000.

The years 1860 and 1861 were uneventful in the history of the Survey, but in 1862, under its auspices, another large collection of minerals was exhibited at the London International Exhibition of that year, Sir William Logan being appointed Commissioner. Upon his return to Montreal in 1863, his great volume on the Geology of Canada was completed and published. Meanwhile, as has already been shown, the existence of the Survey had been extremely precarious, on account of its de-

pendence upon an altogether insufficient annual grant. Accordingly Sir William now addressed a letter to the Minister of Finance under the McDonald-Dorion administration, urging in the strongest terms the necessity of more liberal action on the part of the Government.

The fund provided for the maintenance of the Survey in 1863 was, he pointed out, exhausted, and a certain sum was falling due for the cost of illustrating the report, while the grant of the previous session was insufficient to pay expenses, and allowed nothing for publications. He had, in fact, not only disbursed $4,000 out of his own pocket in the purchase of works for the library, surveying instruments, etc., but in order that the work should be carried on during the year, Parliament having dissolved without granting supplies, he actually advanced the necessary funds, amounting to upwards of $10,000, for the purpose. Shortly after this letter was written a change of Ministry occurred and the Act making provision for the Survey was again renewed for another period of five years. Nothing of notable importance appears to have occurred until 1866, when another mineral exhibit, which was instrumental in attracting much attention to Canada, was sent to Paris in charge of Dr. Hunt and Mr. Richardson

Early in 1869 Sir William Logan resigned the Directorship, and was succeeded by Mr. (afterwards Dr.) A. R. C. Selwyn, an English geologist, who for many years had directed the Geological Survey of Victoria, Australia. Mr. Selwyn, however, does not appear, judging from his earlier reports, to have devoted as much attention to the subject of economic geology as his illustrious predecessor, although in the Report of 1871–72 some valuable information is afforded by Mr. Richardson on the coal fields of Vancouver Island, and by Mr. Vennor in connection with the occurrences of iron and apatite in the Counties of Leeds, Frontenac and Lanark, and of gold in the Township of Marmora. In this year also a first attempt was made to compile mining statistics, figures being given for the three years, 1869, 1870 and 1871. In view of the great developments that have since taken place it may be of interest to quote from these returns. Thus the average annual production at this period is stated as follows

Name of Province	Value of Product at Mine
Ontario	$ 996,982
Quebec	330,209
Nova Scotia, (coal)	1,192,365
Nova Scotia, (gold)	351,266
Nova Scotia. (other minerals)	220,000
New Brunswick	262,288
Newfoundland	233,702
British Columbia (gold)	1,336,066
British Columbia (coal)	151,952
Total annual average	$ 5,044,830

On the grounds, however, that mine owners neglected to make the returns asked for, no further attempt was made to continue this useful work until many years later. The volumes of 1874-5-6-7 are largely scientific in character, much space being occupied also with somewhat trivial details recounting incidents of camp life and travel. Mr. Selwyn, however, appears to have shared the views of Sir William Logan in respect to the importance of exploration in the iron and coal fields of Nova Scotia and Cape Breton, for in the Report for 1874–75, he explains that unusual attention has been devoted to geological work in Nova Scotia, as "the development of coal and iron mines exerts a far greater and more beneficial influence upon the material progress and prosperity of the country than can be ascribed to that of any other product of mining industry." At the same time he complains of the inadequacy of his staff and the urgency of better provision in this respect, pointing out that two-thirds of the time and attention of explorers was then being occupied in making topographical measurements for the construction of the essential preliminary maps.

In 1877 "An Act to make better provision respecting the Geological and Natural History Survey of Canada, and for the maintenance of the Museum in connection therewith," was passed by the Dominion Parliament, but while the scope and objects of the Department were enlarged, so as to include various branches of natural history, there was at first no corresponding increase in the appropriation granted. This was subsequently

remedied, and the Survey commenced to take up natural history work of various kinds, but still showed little disposition to assist the miner in a practical manner. At length, after the issuance of what happened to be a very meagre report for the years 1880-81-82, complaint became so general that a select committee was appointed by the House of Commons to obtain information as to the methods adopted by the Geological Surveys in Canada and other countries in the prosecution of their work, with a view of ascertaining if additional technical and statistical records of mining and metallurgical development in the Dominion should not be procured and given to the public. After hearing the evidence, the committee published a lengthy report, from which the following extracts are taken:—

"The committee . . . notices the serious lack of attention to the mining industries of the country in actual operation. Under the administration of Sir William Logan, but little progress had been made in actual mining developments, particularly in the limited sphere of his labours—the present Provinces of Ontario and Quebec. Since his day, not only has the field of practical mining been greatly enlarged by the addition of the Maritime Provinces with their extensive coal and gold mines in actual operation, but in the previous fields we have to note the discovery and development of the iron and gold deposits in Ontario, the phosphates of Kingston and the Ottawa Valley, the gold of the Chaudière district, and the copper, iron and asbestos deposits of the Eastern Townships, yet we look in vain in the present report for any information, either of a statistical nature of their production, or of a descriptive or geological character, as to their progress or peculiarities. Thirteen pages of the last report suffice to narrate the work of the Survey for the last two years, in connection with the mines in actual operation in the whole Dominion. . . . In the opinion of the committee, the primary object of the Survey should be to obtain and disseminate, as speedily and extensively as possible, practical information as to the economic mineral resources of this country, and scientific investigations should be treated as of only secondary importance, except when necessary in procuring practical results."

In concluding their report the committee strongly recommended the appointment to the staff of the Survey of a duly

qualified mining engineer, whose special business it should be to keep himself and the public informed as to all mining developments and progress, and to procure and preserve full statistical information in respect thereto.

But it may be stated in fairness, that this very report which came in for much unfavourable comment and criticism, contained an account by Dr. Dawson of the discovery and value of the Crow's Nest coal area, probably one of the most important announcements of an economic character ever made by the Survey.

It is to be noted also that in his summary report for 1885, Mr. Selwyn refers to the publication of thirty-seven reports, signifying by their titles their special bearing on mines, mineral deposits and statistics of mineral production, while special examinations of mining districts were begun in 1883 in the Lake of the Woods gold region, the phosphate region in the townships of Wakefield and Templeton; and, in 1884, in the Marmora gold and iron bearing region, and the mining region around the north shore of Lake Superior, as well as in some of the Quebec mining districts. The investigation by the Parliamentary Committee appears, however, to have served some useful purpose, inasmuch as a Mines Branch in the charge of Messrs. Coste and Ingall was afterwards established, and a first and comprehensive statistical report issued in the volume for 1886, in which the total value of the mineral production of Canada for that year is given as $10,529,361. In the preceding volume, Mr. Coste also contributed an interesting paper entitled "Observations on Mining Laws and Mining in Canada, with suggestions for the better development of the mineral resources of the Dominion," and many of the comments in regard to the defects in the law of that time, apply with equal point and force at the present day. The annual reports from henceforward certainly show that a greater interest in mining developments was being taken by the Survey than formerly, and a great deal of valuable information bearing on this subject is made available. Although the Klondike excitement did not eventuate until nearly ten years later, the Survey as early as 1887 called attention to the gold potentialities of the region in a report written by Dr. Dawson, who had associated with him on his expedition, as assistants, Messrs. McConnell

and McEvoy; while in addition to useful facts secured by Dr. Bell relative to the Sudbury district, by Mr. F. D. Adams in the Laurentian country, Dr. Ells in the Eastern Townships, and by Mr. Bowman in Cariboo district, B.C., special investigations in the mining districts were undertaken by Mr. Ingall of the Mines Section. In Part II of the Report for 1887–88 also appears Dr. Dawson's most valuable treatise, on "The Mineral Wealth of British Columbia," which to this day is in frequent request; while in the following year Dr. R. W. Ells reported very fully on the Mineral Resources of Quebec. In the spring of 1889, Mr. Coste resigned charge of Mineral Statistics Division, and was succeeded by Mr. E. D. Ingall.

In 1890, a new Act was passed repealing the Act of 1877, in which the duties and objects of the Survey were set forth as follows:—

(*a*) To make a full and scientific examination and survey of the geological structure, mineralogy, mines and mining resources of Canada and of its fauna and flora;

(*b*) To maintain a museum of geological and natural history and arrange for exhibition such specimens as are necessary to afford a complete and exact knowledge of the geology, mineralogy and mining resources of Canada;

(*d*) To collect and publish full statistics of the mineral production and of the mining and metallurgical industry of Canada; to study the facts relating to water supply, . . . and of mines and mining work in Canada.

The Act also constituted the Geological and Natural History Survey a separate department, instead of a branch or subdepartment of the Department of the Interior. In calling attention to a provision in this Act by which no persons unless science graduates of recognised schools or colleges may be appointed to the staff, Dr. Selwyn in the report of 1890-91, comments as follows:—

By these provisions "it is hoped to maintain the efficiency and high scientific standing of the department, but in order to insure this desirable result a scale of remuneration should be established in the department, more in accordance than it is at present with that which obtains elsewhere, and even in other departments of the public service and in the universities of Canada,

for acquirements and experience such as is required of the technical officers of the Geological Survey, and in view of the risks, hardships and responsibilities they are often called upon to undertake." This representation is alluded to in passing, as it is a grievance of a very real nature which still exists, and it is hoped may in the near future be remedied.

In connection with the collection of mining statistics it may be mentioned that in 1891 an attempt was made to seek the co-operation of the Provinces, and thanks to the good offices of Mr. John Robson, then Provincial Secretary, the endeavour met with ready response in British Columbia. In this regard Mr. Ingall in his report for 1892 writes "The confidence of the mining community . . . . now gained, has resulted in an increasingly hearty response to our circulars," and this statement is borne out by the exceptional value and comprehensiveness of the report of the Division of Mineral Statistics and Mines at this date.

In January, 1895, Dr. Selwyn resigned the directorship of the Survey, and was succeeded by Dr. George M. Dawson. Much more attention was now being given to mining developments, and the first annual report for which Dr. Dawson was responsible is of unusual interest. Thus, an account is given of borings undertaken for petroleum under the auspices of the Survey, at Athabasca Landing; Mr. McEvoy reports on recent developments of economic minerals in the Kamloops area, and refers to the occurrence of cinnabar at Savanas He also describes his observations on hydraulic mining in Cariboo. Mr. McConnell gives a statement of the characteristics of the important mines of West Kootenay; Mr. McInnes reports of the occurrence of economic minerals near Sault Ste. Marie; Dr. Ells describes the occurrences of iron, galena, ochre and mica in the counties of Ottawa, Pontiac and Carleton; Mr. Low calls attention to discoveries of hematite and siderite in the Labrador Peninsula; Mr. Fletcher refers to iron and coal developments in Nova Scotia, while Mr. Faribault's report on gold in this Province is of great practical value. This gentleman in speaking of quartz mining in Nova Scotia, points out that the gold-bearing deposits in that Province are really in the form of saddle veins on anticlinal folds and shows that on a proper recognition of this fact largely depends the success

and future of deep gold mining in Nova Scotia. He also advises the adoption of a method of mining followed in Bendigo, where the occurrences are of a very similar nature, which consists in sinking perpendicular shafts on the anticlinal axis from which cross-cuts and levels are driven to intersect the interbedded saddles. Mr. Ingall, reporting in this volume, complains however that the funds placed at his disposal were insufficient for the prosecution of important mining work which had been initiated by the Mines Section.

In 1895, the Survey undertook a new duty in supplying small typical collections of Canadian minerals and rocks to educational institutions in Canada, and no less than fifty-nine collections of this kind, embracing 6655 specimens, were furnished. In addition, the excellent work of the previous year was extended along similar lines.

In short, during Dr. Dawson's all too short term of office as Director of the Survey both his own-work in the field and that of the department generally was of an eminently useful and practical character. This is well pointed out by Dr. F. D. Adams in his "Memoir of George M. Dawson,"* where he states "his work . . . . contributed largely to great development of the mining industries . . . . during recent years, for his reports, though thoroughly scientific, always took account of the practical and economic side of geology, and accordingly commanded the attention and confidence of mining capitalists, mine managers, and others interested in the development of the mineral resources of the country." Dr. H. M. Ami, in his appreciative biographical sketch also refers to the consideration given by Dr. Dawson to economic work "Through his personal efforts," he writes, "and that of his staff, he did so much to disseminate information regarding Canada's mineral resources, that the mining interests of the Dominion may now be said to be fairly well established upon a firm and non-speculative basis."

Dr. Dawson died suddenly on the 2nd of March, 1901. And from that time to the present the Survey has been without a Director. These duties, however, have been performed by Dr. Robert Bell, who as Acting Director, has had the responsibility of

*Bull. Geol. Soc., Am. Vol. 13, 1901.

the work, but neither the honour nor the emoluments which should go with it. Under Dr. Bell much work of great value has been done by the Survey; but in its relation to the mining industries it is necessary to add that the present system, which remains practically the same as that followed a quarter of a century ago, is by many, competent to express an opinion, regarded as antiquated and inadequate, having regard to present requirements, the growth to which the mining industry has since attained, and the important position it now occupies. And by contrasting the methods adopted by the United States' Survey with those still followed by our own, this complaint appears to have certain justification. Taking, for the sake of example, one branch, the Mining and Statistical Division of the Survey, it is impossible to truthfully assert that its scope or usefulness has been greatly, if at all, extended since the date of its inception. In fact it is currently believed that the officer in charge of the branch has received little, if any encouragement at any time to special effort in this regard. The geological reports themselves too, although frequently of great value from an economic point of view, are with some exceptions, still somewhat unsuitable for general circulation, since they rarely contain the practical details and facts in that readily accessible form which the busy man of affairs, contemplating an investment in any one of our mineral industries, is desirous of having placed at his disposal.

THE ESTABLISHMENT OF THE MINES BRANCH OF THE DEPARTMENT OF THE INTERIOR.

It was doubtless in consequence of a realisation of the requirements in this respect that the Government in July, 1902, established in connection with the Department of the Interior, a Mines Branch, in charge of Dr. Eugene Haanel, Ph.D., who received the title of Superintendant of Mines. The establishment of the Mines Branch did not include a statement of its functions, but a memorandum suggesting the lines on which organization should proceed, was prepared and presented to the Minister.

The work to be accomplished by the Department would, the memorandum states, most conveniently be distributed among the following sections:—

1*st*: *Mineral Resources.*—The general object of the work of this branch to be the collection and publication of data regarding the economic minerals of the country and of the processes and activities connected with their utilization. This to be accomplished under the following two heads:

(a). *Statistics*: Covering the investiga ions into (1) the production, consumption, exports and imports of the economic minerals of he country, (2) the collecting of figures relating to costs, freight, markets, etc. These tabulated on a proper system of classification, with discussions as to the causes of variation of production, exports and imports, fluctuations of market, etc., should be published annually, or at such more frequent intervals as may be found practicable.

(b). *Technological*: Covering the preparation and publication of bulletins and monographs giving information in a concise form regarding (1) the location, mode of occurrence, extent and character of the various economic mineral deposits, (2) Assays and analyses of ores and in the case of building material, tests of strength and endurance of pressure, etc., (3) Description of the method of exploitation, treatment for extraction of metallic contents, or resultant products. The information to be obtained from material already published, but scattered and in a great measure inaccessible, to be supplemented wherever necessary by visit of officer in charge to the respective localities. A separate monograph for each mineral, as coal, iron, copper, nickel, gold, etc. (except building materials which may be written up as a class) to be published, giving all available information in reference to them. The publications specially framed to meet the needs of the public commercially interested in these matters, and annually bound in one volume, entitled "The Mineral Resources of Canada". The separate monographs to be distributed as widely and freely as possible to bring the mineral wealth of Canada prominently before the investing public and thus aid in bringing capital into the country, necessary for the development of its resources.

2*nd*: *Mining Geology.*—Covering the investigation of mineral areas and mining camps, determining the mode of occurrence, extent and character of the ore bodies, and furnishing to the practical miner clues regarding the probable direction in which to exploit his property, and by a careful study of the associated rocks

and their relation to the ore bodies, establishing principles which shall be helpful as a guide regarding the occurrence of similar ores in other regions. This to include the preparation of good topographical and geological structure maps of important mining districts.

3*rd*: *Metallurgy, Assaying and Chemistry.*—The personnel of this section would be occupied in assaying the ores and first marketable products of mines collected by the mining geologists, and performing such rock-analyses as may be required by the mining geologists for purposes of determining the composition of rocks in association with the ore deposits.

The further work of the section would consist in analysing such material as may from time to time be sent to the Mines Branch from outside parties.

CONCLUSIONS.

This historical survey brings us down to the present time, and to review the economic work accomplished by the Survey in a few words, it may be said that practically all the information which we possess concerning the mineral resources of the Dominion has been collected by the officers of the Geological Survey, with the exception of that which we owe to the Provincial Mining Bureaus of British Columbia and Ontario, and to the Mines Branch of the Department of the Interior, all of which have been established within the last few years. But while the Survey has been immense value in the development of the country, the establishment of a separate Mines Branch in the Department of the Interior may be held to indicate that in the opinion of the mining men of Canada the Survey has not in recent years, on its strictly economic side, kept pace with the growing requirements of the mining industry, and that the immense mass of information which it has collected has not been reduced to a sufficiently accessible form.

In this connection, however, it must be noted, that with the exception of experimental metallurgy, every line of work which is set forth as within the purview of the Mines Branch, has been already taken up or is now being prosecuted by the Geological Survey of Canada. In making this statement it must be clearly understood that there is no intention, in what has been said, to

minimise the value of the work accomplished by the Mines Branch of the Department of the Interior since its inauguration, but merely to point out that, while by means of a large special grant placed at its disposal the Mines Branch has been able to produce a number of reports of marked economic value, the production of such reports does not demand the existence of such a separate bureau. Given a properly reconstructed Geological Survey, of which the present Mines Branch might form part, it could employ the same extra grant with at least equal economic efficiency.

Such work, of the highest quality, is being carried out on an enormous scale by the Geological Survey of the United States, which, working in the territory immediately south of us, has to deal with conditions which resemble very closely those obtaining in Canada at the present time. Moreover the work done by this Survey has so emphatically commended itself to the mining interests in the neighbouring Republic that the government have repeatedly extended the scope of the Survey and greatly increased the sum appropriated for its use.

As a matter of fact, our mining community in Canada, while admitting that the Geological Survey of Canada has accomplished an immense amount of good work in times past, points to the immense increase in the volume and value of the mineral output of Canada as shown by the following figures:—

TABLE SHOWING MINERAL PRODUCTION OF CANADA.

	Value in Dollars.
1871	5,044,830
1886	10,221,255
1887	11,321,331
1888	12,518,894
1889	14,013,913
1890	16,763,353
1891	18,698,953
1892	16,628,417
1893	20,035,082
1894	19,931,158
1895	20,648,964
1896	22,584,513
1897	28,661,430
1898	38,697,021
1899	49,584,027
1900	64,618,268
1901	66,339,158
1902	63,865,797
1903	62,532,210
1904	60,343,165

It also points out the present position which the product of the mine holds, as compared with the agricultural exports of the Dominion, as shown by the following figures:—

TABLE SHOWING THE AGRICULTURAL EXPORTS OF THE DOMINION.

	Value in Dollars.
1896	39,659,686
1897	46,377,927
1898	68,919,688
1899	62,528,107
1900	73,281,702
1901	66,872,296
1902	80,705,186
1903	99,420,195
1904	98,300,000(about)

In view of these figures and of the fact that the agricultural interests of Canada have been and are being enormously developed by the Government, through the Department of Agriculture under the charge of a special minister of the Crown, our mining men ask why the great mining interests of the Dominion might not be similarly cared for.

It is not here necessary to enumerate the many ways in which the Governments of other countries do, and our Government could, actively assist in the development of the mining industry. Our views on this matter have already been set forth in a paper read before this Institute and printed in one of the volumes of our Transactions. (Jour. Can. Min. Institute, 1902, pp. 585-595). Our aim here is merely to point out that the mining industries of Canada might at the present time be greatly assisted if the work of the Geological Survey and the Mines Branch of the Department of the Interior was taken up seriously by the Government, correlated, systematized, extended, and made to conform to modern requirements. The duplication which now exists would thus, in the interests of economy, be avoided, and the whole work would be put upon a proper businesslike basis.

If this were done, it is certain that the mining interests of the country would be well served and that the action of the Government would receive the hearty endorsation of everyone interested in mining, and that furthermore, as the value of the work became increasingly evident, the Government would feel justified in providing additional means for its prosecution, so that a larger staff of properly paid and thoroughly efficient men, *au fait* with the modern methods and results of science applied as

to the study of these economic problems, could be permanently employed by the Government in the development of the mineral resources of our country.

All Canadians would be sorry to see the Geological Survey of Canada lose its independent existence, seeing that it is a branch of the service of which, with all its faults, we Canadians have reason to be proud. But if the happy result above indicated could be insured by the appointment of a Minister of Mines who would have direct supervision of this work, the expansion of the Geological Survey into a Department of Mines and Geological Survey, would receive the support of the whole mining community.

A CANADIAN DEPARTMENT OF MINES OR GEOLOGICAL SURVEY.

By J. B. Tyrrell, Ottawa.

For some years past there has been considerable agitation, both in this country and in the United States, on the necessity of the establishment of a Department of Mines, with, in our case, a Minister of Mines in charge of the Department, and in the United States a Secretary whose duty it would be to attend to the affairs of the mining industry.

Devoting our attention entirely to Canada let us consider for a moment what would be the duties and uses of that Department.

The duties of the Department would be confined to an encouragement of the Mining Industry, by detailed descriptions and maps of the known mines and mineral resources of the Dominion; by close investigation in districts where mineral deposits are known to exist, but where their extent or even their character is not well understood; by explorations in unexplored districts with the object of finding new mineralized areas, or areas where valuable minerals might reasonably be looked for; by the preparation of special treatises on industries which appear to lag behind for want of knowledge; by carrying on such researches in laboratories as might seem advisable in the interest of mining and metallurgical methods, and by seeing that the information so collected is fully distributed among the people, so that they may be brought to properly appreciate and rightly use the knowledge so gained of Canada's mineral wealth.

This Department or Bureau, as a business office, engaged in conducting part of the business of the country, should keep in view the furtherance of the wealth and progress of the community. This may seem a very material view to take of the matter, but

mining is a business enterprise, conducted, if it is to be successful, on rational business principles, and the Bureau which is to have charge of the welfare of the mining industry must also be conducted on business principles. Now business principles demand that there should be a reasonable profit on an investment, that profit should accrue within a reasonable time, and that the people to whom the profit accrues or who are making the investment should know of the profit. Violations of this last condition lead invariably to distrust and trouble.

In regard to the support of a Government Bureau the people are the investors, and if they are to continue their investment they must be kept fully advised as to the profits that they are deriving and the benefits that they are receiving from their investment. It is not enough that an individual Minister of the Crown should know that the Bureau is earning a profit for the people; the people themselves must know it if the Bureau is to be an ultimate success.

The interest that the people take in mining will always be commensurate with the money that they make in mining; and a Bureau or Department that will assist the people to make more money out of their mines than they are now making will be supported by the people, but it must be conducted in a businesslike way, on financial principles, and must produce returns reasonably commensurate with the money expended on it.

There is no room for difference of opinion as to the present necessity of a mining Department or Bureau, which would be strong, efficient and thoroughly in touch with the requirements of the mining community, and there can be no doubt that the Government would be prepared to support such a Bureau if the men who were interested in mining would demand it, and at the same time clearly indicate the character of the work and the way in which it was to be done.

Now there is in the country at present a Department, under the Minister of the Interior, which is doing part of the work outlined above, namely the Department of the Geological Survey. Many of the duties assigned to it do not refer to mining, or even to geology, as for instance the study of the plants and animals of the country and the care of a great national museum. These matters are of the greatest interest and importance, and should

be liberally supported, but it is a mistake to any longer confuse them with the investigation into the mineral resources of the Dominion, and no further reference will be made to them here. In the Act constituting and governing the Geological Survey its first duty as therein defined is "To make a full and scientific examination and survey of the geological structure, mineralogy, mines and mining resources of Canada" and further "To prepare and publish such maps, plans, sections, diagrams and drawings as are necessary to illustrate and elucidate the reports of surveys and investigations." "To collect and publish as soon as may be after the close of the Calendar year, full statistics of the mineral production, and of the mining and metallurgical industry of Canada." And again, "The Deputy Head and Director of the Department shall, as soon as may be after the close of each calendar year, make a summary report, to the Minister, of the proceedings and work of the Department for the year, and shall also furnish final and detailed reports to be issued from time to time in such manner and form as the Minister directs."

These regulations, if carried out in an intelligent and business-like manner, are abundantly sufficient to provide for the existence of an advisory department whose duty it is, first and foremost, to further the development of the mining industries of the country.

There are, however, some prohibitory clauses in the regulations governing that department which strike at the very root of the financial life of its members, and deprive them of any interest that they might possibly have in the financial side of mining.

"No person employed in or under the Department shall purchase any Dominion or Provincial lands except under authority of the Governor-in-Council; locate military or bounty land warrants, or land scrip, or act as agent of any other person in such behalf; make investigations or reports relating to the value of the property of individuals. nor hold any pecuniary interest, direct or indirect, in any mine, mineral lands, mining works or timber limits in Canada."

Such illiberal restrictions should be modified, and the members of the staff of the Survey should be treated as honourable men who would not take undue advantage of their positions to

enrich themselves dishonestly, but who might invest any little money that they might be able to save in farms, timber limits, or mines, the same as other citizens, at all events in those parts of Canada in which they were not working at the time. This would turn their thoughts to the financial side of mining and bring them in touch with mining men as no other interest would do.

If, however, it is the fixed purpose of the Government to prevent officials of its Mining Department or Geological Survey from taking any personal interest in the financial side of mining it is clearly the duty of that Government to see that its mining engineers and geologists should thoroughly understand and appreciate mining conditions, and that, no matter in what part of the country they might be carrying on their investigations, whether among the mines that have been most fully developed, or in remote areas where rocks holding mineral wealth may possibly be found to occur, they should be kept thoroughly in touch with the progress of mining knowledge by being sent for a certain length of time each year to the most advanced mining schools, to visit mines, or to meet other men who are studying ore deposits, mines or metallurgical processes. Such visits would serve to broaden their knowledge, quicken their ideas, enliven their enthusiasm, and raise and keep them on a par with the best mining engineers and geologists in other countries. Without such contact and mental communion the ablest man, especially in cases where they are isolated for long periods each year, would certainly lose enthusiasm and touch with the public, and would become mere recluses, incapable of intelligently communicating information which they might acquire or possess.

Finally, the work of a Mining Bureau such as our Geological Survey may be done efficiently and carefully, but unless that work is placed fully, intelligently and attractively before the public it is of comparatively little value.

In this, the most important branch of its work, the Canadian Geological Survey has been quite inefficient. Its officials have prepared reports and maps carefully and conscientiously, and then, as if the isolated life which they have been obliged to lead was not sufficiently depressing in itself, very limited editions of their reports were published, which, instead of being distributed freely where they would do most good, were carefully hoarded

until they became out of date and almost valueless. No abstracts were sent to the newspapers, and the information contained in them was almost as worthless, as far as the spreading of knowledge among the people was concerned, as if it was still hidden in the rocks.

The conclusions arrived at in this short paper, are as follows:—

A Government Department or Bureau to advise the Minister of the Interior in regard to mining affairs is necessary.

It was clearly the intention of the Act constituting the Geological Survey that it should be such a Bureau.

It can be made an efficient Bureau for the purpose for which it was constituted:—

By allowing its officials to invest in mines the same as other members of the community, or at least with only moderate and reasonable restrictions.

By insisting that all the officials, no matter on what work they may be engaged, keep in touch with mining conditions in other parts of the continent or of the world, and

By seeing that the public is kept fully informed of the results of the work of the Survey.

DISCUSSION.

Mr. Hardman:—Referring to some of Mr. Tyrrell's remarks, to my mind when any official of a Government has an opportunity of becoming interested in affairs or properties upon which he may be called on to report officially, that moment that man's usefulness is ended. Compiliations heretofore have been made by men who had no financial interest therein. If the law was changed so that a report on any particular district was made by a man financially interested in that district, that moment such publication would lose its status, and would not be accepted in the same strong sense of authority that it is to-day. I make this criticism entirely in the interests of the Government. The usefulness of the Survey Department would be very much impaired if any member were allowed to be pecuniarily interested in mining

properties; or should any such radical departure be taken from the standard that has been maintained for the last fifteen or twenty years.

Mr. INGALL:—I would like to say a word on behalf of the suggestion introduced by Mr. Tyrrell; that of allowing the members of the staff of the Geological Survey to accept pay for professional work outside of their official duties and salaries. It has not been done so far, and I hope it will never be done. I am sorry to hear that the Ontario Government has permitted a similar kind of thing and I hope that the discussion that has taken place here to-night may be reported to the authorities in Toronto in order that the practice there may be discouraged. It does injury. I would like to endorse the point made that we would not get information from mining men unless we were believed and known to be absolutely disinterested. At every turn we meet with corroboration of this view. You are told, bring one of your permenent officers to investigate such and such matter and he can have all the information desired, providing you promise us you won't use it so as to be detrimental to our business. You see that point has actually been proven in practice, so that one must strictly keep clear of entanglement in all work of this nature.

Mr. MILLER:—For fear there might be some misunderstanding as to the last remarks of Mr. Ingall, I might say that the members of the permanent staff in Toronto are not permitted to have interest in mines. If they have such interests at the time of their appointment they must drop them. It is only the men we employ temporarily who may or may not have such financial interests, and these men are allowed to make private reports at times, but the permanent staff are controlled just as closely as are the members of the Geological Survey at Ottawa.

Mr. LOW:—It is about our only remaining object of pride that we cannot be bought, even if we do get paltry salaries, and we would feel it very keenly indeed if that one privilege were taken away from us.

THE REVISION OF THE MINES ACT OF ONTARIO.

By J. M Clark, K.C., Toronto.

Many resolutions have been passed and numerous recommendations made with reference to the revision of the Mines Act, which is to be undertaken at the next session of the Ontario Legislature. These resolutions and recommendatons have been varied, but it is noteworthy that at almost every meeting at which the Ontario Mining Law was discussed there was a demand for a mining law to be enacted by the Legislature and to be applicable to the whole of the Province. This demand is wise and fully justified. Sir Frederick Pollock has well said that the criteria of just laws in a civilized community are generality, equality and certainty, and few men are more competent to speak on the subject.

A good mining law must satisfy these three tests. It should be steadily kept in mind that our mining laws, like other laws, should be made by our legislatures and parliaments after full discussion by the representatives of the people. The function of a government and its officials should be to carry into effect the laws so made. The distinction between the law-making powers of the legislature and the executive and administrative powers of the government is too often ignored. In view of the unanimity of the demand for a uniform mining law, it is to be hoped that in the interests of the mining industry a stable and well considered statute will be passed by the Ontario Legislature which shall not be subject to sudden alteration by Orders-in-Council.

The rights of explorers and prospectors should be clearly and distinctly defined, and also what has to be done to protect any discoveries they may chance to make. The mineral areas of Ontario have largely to be yet explored, and this will not be thoroughly done unless the pioneers are certain of protection

and justice. The conditions upon which mining locations or claims can be held should also be clearly and plainly set forth.

It is for the Legislature to say what these conditions shall be, and for the Government to enforce the enactment of the Legislature.

In framing such a law for submission to the Legislature, the Government have many difficult questions to consider, many complicated problems to solve. The Government and the Legislature have to consider not only the prospector and discoverer, but likewise the miner and the investor in mining enterprises, and also the interests of other industries, such as, for instance, the lumbering industry, and of the public. The history of mining development in this Province has to be carefully considered, and it may be taken for granted that the best results will be obtained by making the necessary amendments and modifications of our existing legislation rather than by attempting an entirely new Act, although a new Act might easily be drawn that would be more perfect theoretically and more rigidly logical. The practical results of drastic and violent changes in our laws do not warrant the risks of such an experiment with our mining Act.

The main object is the development of our mining industry, which is of increasingly great importance. If this development is to be as great as it should be, there must be certainty and stability in our mining laws.

The history of our legislation shows that suggestion of gaining revenue by the imposition of royalties is a most unwise one.

Twice already has a system of royalties been introduced in this Province, and each time the results have been so disastrous that the royalties so imposed have been abandoned and repealed. There seems no doubt that like causes would again produce like effects. No one suggests that the mining industry should not bear its fair share of necessary provincial taxation; but no special or arbitrary burdens should be placed on it.

YUKON MINING LAWS.

By J. B. Tyrrell, M.E., Ottawa, Ont.

In presenting a short paper on the Yukon mining laws, it is not the author's present purpose to enter into generalities, or to attempt to explain what an ideal mining code should contain; but rather to present some of the main provisions of the laws which have been in force for the past eight years, and to point out the advantages and disadvantages of those provisions.

The productive mines of the Yukon have been confined to gold bearing gravel deposits, and therefore these remarks will be confined to the laws which have governed the workings of these deposits.

The difficulties of framing a mining code which will meet the wishes of the majority of the members of any mining camp will always be very great. In the first rush to a new camp every man wishes to obtain a claim. This is a proper and laudible desire, and one which, in the interest of the development of an uninhabited country such as much of Northern Canada, should be fostered to the greatest possible extent. There is nothing that will attract a population into any country as quickly as the discovery of precious metals therein, and when a country has had a population drawn into it by this means, a population usually composed of energetic, enterprising, quick-witted men, men prepared and willing to make use of any of the natural resources with which they may find themselves surrounded, it is certainly good policy and high statesmanship for the Government to make such laws as will encourage and induce these men to acquire such property as they wish to develope, and become permanent settlers of the district. At a later date, after the properties so acquired have been developed, and some few have proved to be rich and many others poor or worthless, the great majority of the people are disappointed, and are often willing to listen to the anarchistic mouthings of demagogues who have

ittle to recommend them but their long tongues and empty heads. Led by such men the dissappointed majority call for changes in the laws which will take from the busy successful men the properties which good luck or foresight has put in their hands, and distribute these properties among those who have been less successful in the race. In this stage of a camp's development, a government strictly by the majority of the people of the locality itself, would usually mean ruin in a very short time, for the prosperous men who had given their thoughts and labor to its upbuilding would be driven out, the country would be quickly sacked by the disappointed ones who had become plunderers, and would then be abandoned. The usual cry of the demagogues is that the owners of the land are not working it as energetically as they should, and that if the present owners were driven off they would work it to much greater advantage.

It is the clear duty of a strong and honest Government, which has the ultimate progress of the country at heart, to disregard this clamor and to protect the vested interests of the mine owners. It should see that these men secure a permanent interest in the country, and allow them to make a home in it, and should discourage them from working the ground out hastily and inefficiently in order that they may go elsewhere, possibly to a foreign country, to enjoy the wealth snatched from Canada. It is almost inconceivable that any Government should spend millions of dollars in order to induce settlers to come into a country and that it should at the same time insist on those who come into the country voluntarily leaving it as quickly as they possibly can.

If the camp should fortunately pass unharmed through this disappointment stage, and the mining of the country should remain in, or pass into, the hands of business men with capital, either produced in the country itself or brought from elsewhere, it has then a possibility of a long and almost permanent life, and such other industries as the country can support will grow up around the mines; for, while the statement may seem a rash one, it is probable that there is hardly any land on this continent south of the shores of the Arctic Ocean which will not ultimately support an industrial population. If the progress of the Dominion during the last twenty years is considered, it will be recognized that he would be a foolish man indeed who would undertake to say that

any part of our country is valueless, or even that any part is valueless except for its mines.

A mining code should therefore encourage men to search for and find valuable mineral, should provide for the quick and easy acquisition of the mining property after mineral had been discovered on it, should protect the owners in the employment of any rational methods which they care to adopt in extracting the values from the ground, and should encourage them to become permanent residents of the country, and to use the riches extracted from the ground as far as possible for the country's development and for the furtherance of the growth of such other industries as it may be able to support.

MINER'S LICENSE.

According to the mining regulations now in force in the Yukon Territory, every man having any interest in mining property must hold a Miner's License, and no location of a mining property is valid unless the locator is at the time in possession of such a license.

As a quick and easy method of raising a revenue from a throng of enthusiasts rushing to share in the advantage of some new strike, this tax has probably no equal. Seven or eight years ago every man in the territory expected or hoped to be a mine-owner, and so every man took out a license, and the amount of the revenue thus contributed to the Government was very large. In the year ending June 30th, 1899, the amount collected from this source alone was $227,354.13. Now the number of those who buy licenses is comparatively small, being limited to those who actually own mining property, and men who deliberatly go prospecting

If this tax is necessary it should be levied on every man whether in the towns or at the mines, with the one exception just to be mentioned, for mining is the only serious producing industry in the territory and all the people are supported by it either directly or indirectly. If the miner is taxed, the storekeeper should also be taxed, and if the one cannot hold his property without a license, the other should not be able to hold his account against the miner without a license. At present it is a special tax on the vital industry of the country, and is bad.

In case the tax continues to be levied, the exception spoken of above is the prospector. He certainly should be free from impositions of any kind, and on the contrary should receive the greatest possible encouragement to prospect. People travel about the territory for many reasons and on many errands, and often find themselves favorably situated for doing a little prospecting, but as a rule such travellers have no licenses, and so, as they can not stake or record claims if they do make discoveries of ore, they will not prospect. It is quite usual to hear the remark from hunters and travellers that they had seen very promising surface showings, but that they dare not do any definite development work as they were not in possession of licenses; for if they should find values, some one else with a license might come along and stake a discovery over their heads. One may sneer at the possibility of such men finding rich deposits of ore, but many of the richest mineral discoveries on this continent have been stumbled on by just such wanderers, and it is the height of folly to say to such men, "we will not allow you to prospect." One rich strike by such men would be worth more to the country than all the license fees that have been collected in the Yukon Territory from the time when gold was first discovered in it up to the present.

Again, a man goes into the wilderness with the deliberate purpose of prospecting for precious metals. Every one recognizes that his success would mean much to the country, but outfit and provisions are expensive and he has the greatest difficulty in getting together sufficient to last for even a few months in the back country. At such time any expenditure of money, however small, is a serious consideration, and it is a great hardship and discouragement to be told that he may not go out to prospect or attempt to develop the country until he had first paid out, for a Miner's License, part of the money saved or collected for a grub-stake.

In Alaska no license is necessary, and the whole country is free and open to the prospector,.

CLAIMS.

Since the 30th of September last any new claims staked are 500 feet long, presumably in the direction of the run of the pay-

streak, and from a 1000 to 2000 feet wide, but for several years previous to that time they could be staked only 250 feet long.

All claims should be of the same size, and should be as nearly as possible square. This is the principle generally adopted in regard to quartz claims, and there is no valid reason why it should not be adopted for placer claims as well, especially such placer claims as are found in the Yukon territory, where the gold values are just as completely covered and obscured as they are in many quartz claims.

1000 feet square would be a reasonable size for placer claims. In Alaska, which is but a few miles distant across an invisible boundary line, the locators are given 1320 feet in the direction of the paystreak, and 660 feet in a transverse direction, and it is unreasonable to expect that prospectors will explore a country where they can obtain claims only 250 or 500 feet long, when they are but a few miles distant from a similar country where they can obtain claims 1320 feet long.

These claims should be located by two stakes, No. 1 stake at one end of the claim, and No. 2 stake 1000 feet up or down the valley from it. No. 1 stake should govern the middle line of the claim which would extend 500 feet on each side of it, and No. 2 stake should be subject to change of position on survey, so that the claim would follow the general direction of the valley. Thus the claim would be located with reasonable accuracy from the first, the locator would obtain the ground he staked, and others would know what ground was staked and what ground was open, so that they could also stake properties.

According to the present law the locator, when he stakes, is uncertain as to exactly what ground he will finally receive, for the position of his claim is determined by a creek base line, which is almost always run after the claims on a creek are located. For instance the bottom of the valley of a creek may be 3000 feet wide, and the creek may flow near one side of the valley. As water is very necessary for washing the gold from the gravel the locator will probably drive his stakes beside the creek, and feel confident that he has a claim on the creek. A surveyor is sent out from Dawson to run a base line on the creek, and he runs it down the middle of the valley, though in places on account of the windings of the valley it will be nearer to one bank than to the other,

and the present law declares that the unfortunate locator is to receive a thousand feet on each side of that base line. Thus his original stakes may not be on his own ground at all but may be far to one side of it, and he may be deprived altogether of the ground which he wanted, which he believed he staked, and which he supposed he owned.

Again as the original claim depends for its position on the base line to be run subsequent to its location, and not on its own stakes, the amount of ground that is still open to location on one side or the other is altogether uncertain. It is true the ground may be staked at random by stampeders, but no serious and definite development work will be done on it until the positions of the claims are definitely fixed by the base line, which may not be for a couple of years after their location. In the meantime interest in the district may die down, the people may go elsewhere, and the prospecting, which would have been carried on enthusiastically at the time, if the men had known the exact ground on which they had a right to work, is indefinitely postponed.

REPRESENTATION

The present law provides that $200 worth of work shall be done on each claim each year, and the regulations of the Gold Commissioner's office fix a scale at which certain classes of work shall be appraised. On concessions, which are larger areas of low grade ground, it is provided that $5,000 worth of work must be performed each year, such work to be approved by the Minister of the Interior.

The intention of these regulations is clear, namely that a man must work his property more or less continuously, or leave it and allow someone else to work it.

In this connection however it should be remembered that a gold mining property is only of value on account of the gold which it contains, and that when this has been extracted its value has disappeared, and that care and economy in the extraction of the gold are of far more ultimate value to the community than hasty and wasteful procedure.

The above regulations have now almost entirely lost their original significance, and on claims which the owner deems it ex-

pedient to hold over for a time, the representation work has dwindled into a mere tax of $200 on each claim, a tax from which neither the owner nor the country derives any benefit. During the past year there were probably 4,000 claims on which this perfunctory representation work was done, indicating a waste of valuable capital to the extent of $800,000.

When it is considered, that concentration of capital is so urgently needed to develop and work the vast gravel deposits of the territory, this undirected and wasteful scattering of capital and energy is greatly to be regretted.

The policy which should be pursued will be indicated under the head of title.

TITLE.

Claims are held under annual grants from the Department of the Interior and must be renewed from year to year. This renewal is subject to any changes in the laws and mining regulations, and to the acceptance of the annual representation work by the Gold Commissioner. Concessions are held under leases for 20 years, subject to an annual rental, and also to the acceptance by the Minister of the Interior of annual representation work of the value of $5,000.

For the purpose of the small holders, who wish to take what values they can extract quickly from the ground and then leave the country, the annual leases of claims are in most cases satisfactory, though they do not encourage the lessees to become permanent residents. Under them the ground is mined hastily and almost invariably badly, and what gold is left in it is very difficult to recover afterwards. Such leases have a tendency to keep the land divided into small parcels, and may satisfy the requirements of a roving population, but as a means of furthering systematic mining, encouraging the investment of capital, and attracting a permanent population they are an utter failure. Capitalists are not anxious to invest in remote and speculative mining enterprises unless the title to the property invested in is perfectly secure, and there can be no perfect security in an annual lease dependent on the acceptance of certain conditions by an official, and forfeitable for such trivial causes as the failure of an agent to renew a miner's license, or to pay the annual renewal

fee (or rental) on the day appointed. Shareholders of companies will trust a great deal to their directors and managers, but such possibilities of loss will always loom up very large before them.

The remedy for such a state of uncertainty is very simple. Those who wish to hold their ground cheaply on an annual lease should be allowed to do so as long as they remain on their claims for a reasonable part of the working season each year, say for at least three months out of the twelve. In this way representation and development would go hand in hand, for the two terms should be synonymous if the former is to have any validity at all. The necessity of residence on a claim would also encourage men to remain within the district.

After a man had placed efficient machinery on his claim, and had opened it up and shown its value he should be given a title to it which would be perfect for 20 years at least without any possibility of loss or forfeiture on account of the acts or omissions of any one.

In Alaska a patent to a mining claim can readily be obtained after a reasonable amount of development work has been done on it, and capital is in consequence flowing into that country in abundance, for the carrying on of hydraulic and other mining enterprises on a large scale, while in the Yukon territory, with its short forfeitable leases, it is almost impossible to induce capitalists to consider investments in properties which would otherwise be most desirable and attractive.

DISPUTES.

Disputes as to boundaries, water-rights etc., should be settled by the Gold Commissioner or Mining Inspector on the ground, where the questions in dispute would be clearly in evidence, and where the parties to the suit would be able to explain fully the matters on which they disagreed and also where the witnesses would be free to speak under conditions which they understood and with which they were familiar.

The majority of miners and prospectors, being accustomed to working in the country, at a distance from cities and towns, and with few people around them, are able to explain themselves very clearly when in the midst of these surroundings, and when they can point to and show the places and things of which they

are speaking, but if you put these same men in a crowded court room in the city, with every thing around them strange and uncongenial, and oblige them to point out positions on a map which they but imperfectly comprehend, and describe places and things in set phrases understood and demanded by the court, but unfamiliar to the witnesses or parties to the suit, the judge has not one chance in a hundred of getting as clear a grasp of the situation or dispute, or of giving as fair and equitable a decision as if he were on the ground.

Besides the fuller justice of decisions so given, such a procedure would entail far less loss of time to the miners, and the miners' time is the time which is of greatest value in the development of the country, and it would also mean great saving of money to them, for the cost of litigation in the Klondyke during the past few years over questions of boundaries alone has been enormous.

On this subject the author cannot do better than quote the evidence of such an impartial observer as Mr. J. H. Curle, the eminent English mining engineer, who spent part of the summer of 1901 in the Klondyke district, and who, in the second edition of his book "Gold Mines of the World" writes as follows:

"The Gold Commissioner, his assistants, and the Claim "Inspectors seem to have no power—or to be afraid to use it. "Their remedy is, 'Oh, take it into court.' Dawson, as a conse- "quence, reeks with lawyers and litigation. A couple of Aus- "tralian mining wardens, of the old school, who would ride up "the creeks themselves, interrogate the parties to a dispute, and "settle the matter on the spot—sticking the boundary and "water-right pegs into the ground themselves, and warning the "men to touch these at their peril—would do more good than "the dozens of officials there now, and would soon empty the "courts of litigants."

THE OCCURRENCE OF DIAMONDS IN THE DRIFT OF SOME OF THE NORTHERN STATES.

By Dr. Robert Bell, Chief Geologist. Geological Survey, Ottawa.

The finding of diamonds in the drift at several points southward of the Great Lakes has been noted by Dr. Geo. F. Kunz, Mr. Frank Leverett and more particularly by Professor Wm. H. Hobbs. Mr. Archibald Blue has written a summary of the facts on this subject up to 1900 in the Journal of the Canadian Mining Institute for that year. At the recent meeting of the Geological Society of America at Ottawa, a paper by Dr. Kunz was read which gave some additional information on this subject.

At the present time the most interesting question in connection with this matter is to locate, if possible, the area or areas from which the diamonds have been derived, and the writer will confine his remarks to this point.

The region in which the diamonds have been found in the drift extends from the southwestern part of Ohio in a northwesterly direction through Indiana, Michigan and Wisconsin, a distance of about 600 miles. If these stones have all been derived from one source they must have taken widely different courses from the parent rock in order to have reached the several localities where they were found. Some of the writers on this subject have assumed that by plotting backward the courses of the glacial striæ from the places where the different finds have been made, the region where these lines would nearly converge would be the probable locality, and they have arrived at the conclusion that this is somewhere in the Labrador Peninsula.

There are a number of reasons for not accepting this conclusion, among which are the following: The striæ appealed to for evidence, belong, no doubt, to long separated intervals of the glacial period. Even when we can trace one set of striæ back for a considerable distance, it is found that the drift or till along its

path may consist largely of materials which do not occur anywhere upon its course. This is because large quantities of till have been removed from other regions by pre-existing ice-sheets which travelled in one or more different directions. What must have been extensive systems of glaciation, as shown by the composition of the till and by their effects upon the solid rocks, have had their striæ almost entirely obliterated by newer systems running in very different directions In questions of this kind, great care should be taken to distinguish between the general course of the striæ and mere local groovings, sand this does not appear to have been done.

Glacial striæ have nowhere been proved to run in a nearly straight course for such great distances as would be necessary to carry those in question back to an area anywhere near to Hudson Bay. The distance from southern Ohio to the nearest point of James (Hudson) Bay is over 1,000 miles and to northern Labrador fully 2,000 miles.

Between the Great Lakes of the St. Lawrence and northern Labrador, the glaciation has not all occurred within any moderately short interval of time. On the contrary, the writer has shown (Glacial Phenomena in Canada, Bull. Geol. Soc. of America 1885), that it took place through a long period, the work shifting from south to north and that it still continues in Baffinland at the present day.

The author has from personal experience a good knowledge of the glacial conditions of the northern regions, as well as around the Great Lakes themselves, and also around Hudson Bay and straits and in Baffinland beyond the latter, although he has not yet laid down upon a map the directions of the striæ at the almost innumerable localities where he has noted them throughout the great regions just mentioned.

In proceeding from the southern extremity up the east coast of Hudson Bay the course of the ice grooves changes from southwest to west and then to north. The glacial debris, pushed north along the coast, has been carried completely across the western part of Hudson Strait, so that if diamonds had existed there they would have been driven in the opposite direction from Ohio instead of towards that state.

In Baffinland the striæ run south, curving somewhat to the eastward in approaching Hudson Strait, while south of the Strait they run northward, curving eastward as they approach that great channel. In the paper already referred to, the writer shows the probability of the former existence of a centre of glacial dispersion in central and eastern Labrador and another to the west of the northern part of Hudson Bay.

On the Canadian shores of Lakes Superior and Huron the glaciation has not always been to the southward. When the basin of Lake Superior was filled with ice it flowed out to the west and east. Along the north shore of Lake Huron the flow at one time was eastward. This is proven by the transportation of the glacial debris, including boulders and pebbles of jasper conglomerate. The most recent sets of striæ, along this shore, however, run southward and southwestward.

The jasper conglomerate occurs only within a limited area at the eastern extremity of Lake Superior and north of the St. Mary River. Owing to this fact and the striking and unique character of the conglomerate itself, which renders it easily recognized, this rock may be selected to trace the course of the materials of the drift from this region. It is met with in the drift all along the north shore of Lake Huron; and from the south side of Georgian Bay fragments of it may be traced southward through Ontario into Ohio and westward through Indiana and Michigan to the vicinity of Chicago. A fine large boulder of it from the vicinity of Ann Arbor may be seen on the grounds in front of the state university of that town.

The basin of Lake Superior is situated in a volcanic area which has had its origin in remote geological ages. The volcanic and igneous rocks, together with the shales containing carbonaceous matter, which are so abundant in the Lake Superior region, may well be supposed to furnish materials from which diamonds could be derived, and these may have been carried in nearly the same course as the jasper conglomerate into all the states where diamonds have been found in the drift.

In the Muskoka district on the east side of Georgian Bay there is an area of peridotite rocks which may also have furnished diamonds. In the American Geologist for July 1894, Professor Hobbs says, in regard to the source of the diamonds found near

Milwaukee, that "it is interesting to note that in the Menominee region on the northeastern boundary of Wisconsin are basic intrusive rocks which cut shales containing considerable percentages of carbonaceous matter, thus reproducing the conditions which obtain at the South African diamond mines." This may be the correct explanation of the origin of some of the diamonds and there may be several centres from which the gems may have been derived.

Another matter in connection with the supposed source of the diamonds in question should be considered. If it were possible that the diamonds could be transported with the drift through the great distance from the northwestern portion of the Labrador peninsula to the location where they are now found, it would still be requisite that some of the rocks in that region should be of such a character as to give promise of yielding diamonds. Instead of this, we know that the whole of that territory consists of the monotonous primative granitoid gneiss which is peculiarly barren of minerals of any kind beyond its elementary constituents.

Against the theory of the diamonds originating in this region, we have, therefore, the facts that the drift did not move southward except in a part of the intervening regions, that even if it had done so, the distances were too great for any of it to have reached the localities where the diamonds have been found, and that the rocks of the region of supposed origin are most unlikely to have produced diamonds.

It is true that beyond Cape Jones, there is a narrow strip of Animikie rocks on the east side of Hudson Bay, but, as above mentioned, the glaciation on that part of the coast ran due west, and farther up the coast it was northward all the way to Hudson Strait.

SOME LABORATORY EXPERIMENTS IN MAKING STEEL DIRECTLY FROM IRON ORES WITH THE ELECTRIC FURNACE.

By J. W. Evans, Mining Engineer, Desoronto, Ont.

The following experiments were begun in April, 1904, but, as the writer had only his spare moments to devote to the work, it was not until September, 1905, that satisfactory results were obtained.

In the first experiment a fire clay furnace was used with electric energy supplied by a small Brush direct current generator of 20 amperes at 35 volts, driven by a 2½ H.P. gasoline engine.

The results were not satisfactory, the voltage being too low to keep the arc alight, and it continually went out causing annoying delays, also the amount of ore treated at a charge was very small, and, although some small steel buttons were obtained, it was decided to work on a somewhat larger scale. Not being able to purchase a larger generator, the writer built the alternating current generator and exciter shown in photograph No. 3, during the winter of 1904-5. Plates No. 1 and 2 show the workshop. This occupied his spare time that winter, and it was not until June 1905 that smelting operations were begun again. The generator was built to furnish 30 amperes at 50 volts, and gives from 40 to 50 amperes at 50 volts for short runs without undue heating, and is driven by a 4 H.P. gasoline engine, furnishing energy for the three furnaces shown in Diagrams No. 1, 2 and 3.

Description of Furnaces.

Diagram No. 1, is a furnace of the reflected arc type as devised by Moissan.

In Diagram No. 2, the electrodes are placed in a vertical position, the lower electrode passing through the furnace to the carbon crucible, which rests upon carbon packed round the electrode. The

lining of the furnace consits of corundum mixed with 8% of tar and is baked for 48 hours in a hot oven before use.

The carbon crucibles are made of ground carbon and tar stamped out in a large sized cupel mould and baked in the same manner.

The furnace is supported by an iron ring stand such as is used in laboratory work.

Diagram No. 3 shows a furnace arranged for either fire clay, magnesia or carbon crucibles, and has the electrodes suspended above the furnace, they can be raised or lowered at will, and the arc gap can be regulated. The holder for the electrodes is made of hardwood (See Fig. 4, Diagram No. 3.), with two $\frac{3}{4}''$ holes bored as shown. A "V" shaped cut between the electrodes, and extending almost through the wood, allows the holder being bent as shown by the dotted line. An adjusting screw regulates the amount of bend, and two handles projecting out behind enable the electrodes to be put in contact to start the arc, when, upon releasing them, they spring apart to the distance set by the adjusting screw. This makes a cheap and efficient holder. The carbons should fit the holes snugly; if loose, a screw at "f" holds them securely. As the iron ore, when fused, has a tendency to draw down the arc, the arc plays round the crucible at the extreme ends of the electrodes, and in both this furnace and in No. 1, the writer has made a mild steel from the ore in 20 to 25 minutes taking an ounce of ore at a charge. By adding more ore from time to time, a continuous furnace can be made of each of the above furnaces until the capacity of the crucible is reached; the large buttons shown were obtained in this manner. When using a carbon crucible a coarse-grained pig iron is first obtained, by leaving this in the furnace too long it takes up considerable carbon and puffs up into an iron carbide. No. 2 Furnace having the current passing through the charge, and requiring a carbon crucible, is not as quiet a running furnace, and the product is not a fine steel but a coarse-grained pig iron; buttons of steel were obtained from this furnace, but it does not work as well as the suspended or reflected arc furnaces. The writer is now using a special design of furnace which completely reduces an ounce of ore in from 15 to 20 minutes, and converts it into a fine steel.

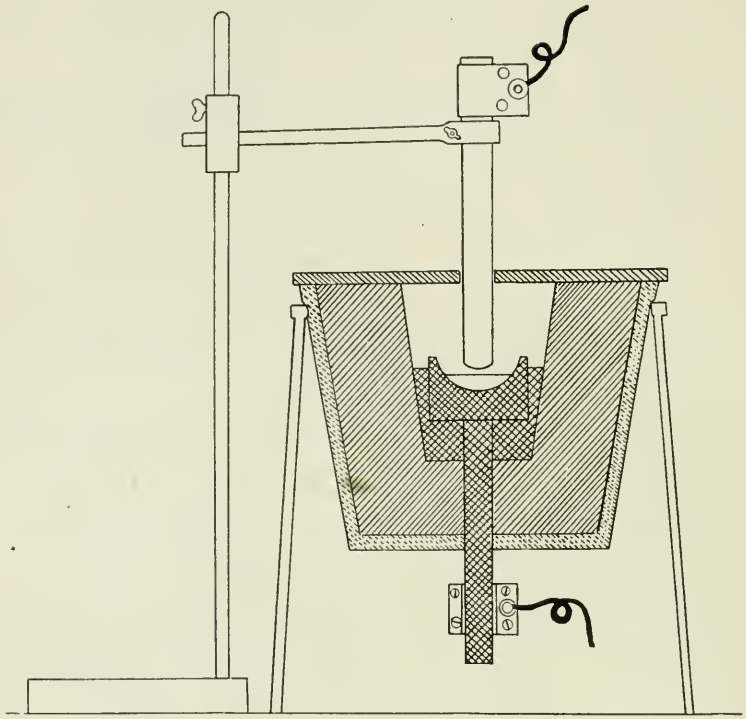

DIAGRAM NO. 1.

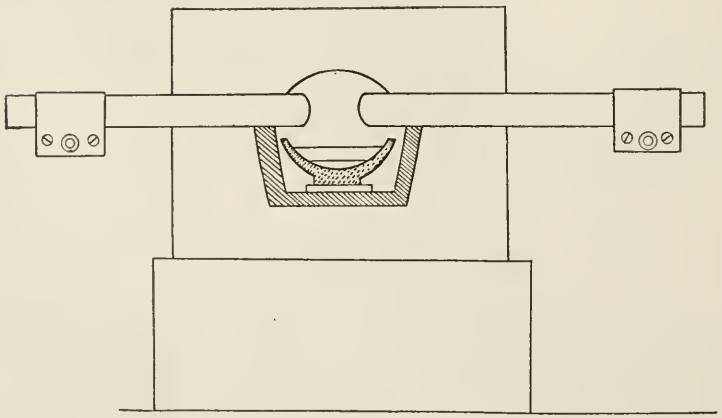

DIAGRAM NO. 2.

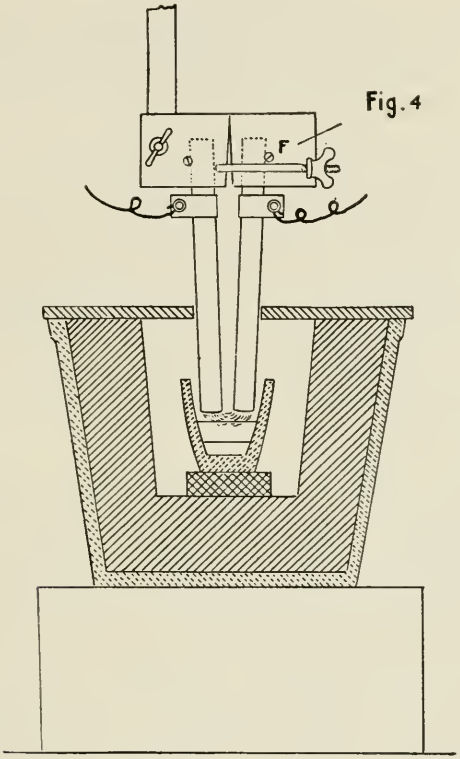

Diagram No. 3.

Furnace Linings.

For furnace linings the following substances were tried, fire clay, magnesite, carborundum and corundum. Carborundum or corundum mixed with 8% of tar, when thoroughly baked, makes a very satisfactory lining, although it must not come in contact with the iron charge. An inside lining of magnesite overcomes this difficulty. At present the writer is using fire clay crucibles in a furnace lined with corundum and tar, the crucibles being broken after each operation. Pouring the slag and steel was tried, but it was found that such small quantities cooled too quickly for pouring.

REDUCING AGENT.

As Charcoal is the only available domestic reducing agent obtainable in North Hastings and other parts of Eastern Ontario, the experiments were confined to its use as a reducing agent.

ORES HIGH IN SULPHUR AND TITANIUM.

In treating the sulphurous iron ores over 92% of the sulphur was slagged off, and by varying the amount of lime, better results should be obtained. In treating the titanium iron ores, steel was produced which did not contain a trace of titanium, but, as the writer wished to retain a portion of the titanium, the quantity of lime in the charge was reduced and the result showed that the titanium contents in the steel can be readily governed in this way, although the temperature of the furnace will have to be kept as constant as possible.

When one considers that there are immense bodies of titaniferous and sulphurous iron ores in Ontario and Quebec, and that fine water powers are within reach of many of these deposits; that there is abundance of wood for charcoal and quantities of limestone for flux in the immediate vicinity of the ores; that in treating them by this method one does away with all preliminary treatment, such as magnetic separation, roasting, etc., and obtains steel in one single operation. It does appear that the day is not far distant when Ontario and Quebec will be able to do their share in furnishing fine grades of machine, spring and tool steel, not to mention the possible valuable by-products, such as titanium-silicon, etc. obtainable from the titanium slag, etc.

In the writer's opinion it is doubtful if Pig Iron can be made in Canada by the electric furnace cheaply enough to compete with the blast furnace at the present time, but the finer grades of steel undoubtedly can be made profitably when smelted directly from the ores.

IRON SANDS.

This process should also solve the question of treatment of magnetic iron sands, of which there are large deposits in both Ontario and Quebec, and the writer has made a mild steel containing .05% carbon from magnetic sands from the St. Lawrence

River. These sands could be dredged and dried, magnetically separated, and conveyed direct to the furnace at a considerable saving in cost over mining and crushing iron ore.

Analyses of Ores and Steel.

The following analyses of the Ores, and of Steel obtained from them may be of interest:

Analyses of Ores for Iron, Titanium and Sulphur.

Coe Hill Ore (*Sulphurous*		Bowen Mine Ore. (*Titaniferous*).	
Iron	68.01%	Iron	45.17%
Sulphur	1.01%	Titanium	7.44%

A.

Analyses of Steel from Coe Hill Ore.

No. 1.		No. 2.		No. 3.	
Silicon	.01%	Silicon	a trace	Silicon	.04%
Sulphur	.12%	Sulphur	.17%	Sulphur	.08%
Carbon	.05%	Carbon	.07%	Carbon	.06%

B.

Analyses of Steel from Bowen Mine Ore.

No. 1.		No. 2.		No. 3.	
Silicon	.62%	Silicon	2.31%	Silicon	.05%
Titanium	.37%	Titanium	1.02%	Titanium	none
Carbon	.51%	Carbon	.84%	Carbon	0.87%

When much lime is used as flux, titanium slags off readily. If titanium is retained in the steel, by lowering the amount of lime a large portion of silicon is retained also.

In B. No. 2, the proportion of ore to lime was ten of ore to one of lime. In No. 3, ten of ore to two of lime.

Plates 5 and 6 show the writer's laboratory where most of the determinations were made, but the writer's thanks are due to Mr. A. G. Burrows, of the Provincial Assay Office, Belleville, who made several of the determinations. A number of samples of the ores, steels and slags are shown in the case on view, duly marked with the analyses, and locality, etc.

DISCUSSION.

Mr. OBALSKI.—I should like to know from Mr. Evans if he has been using the magnetic sand concentrated or in the rough state. If there is anything regarding the cost of smelting, I would be glad to know about that too.

Mr. EVANS.—The sands used were concentrated. They were sent to me from Montreal, and as far as the cost is concerned, of course, I could not go into that with accuracy owing to the experiments having been conducted on such a small scale.

Mr. OBALSKI.—Do you think it would be a commercial proposition in the near future.

Mr. EVANS.—I should think so, so far as steel is concerned. I refer only to tool steels and fine machine steel. I do not include structural steel or pig iron.

PRESIDENT SMITH.—Mr. Evans has some very interesting specimens of some of the steels made in the manner indicated in his paper.

MAJOR LECKIE.—I think there is an opening for the electrical furnace in another way. I carried on some experiments a year or so ago, in the way of saving the iron from the slag, and some trials along the same line were also made by my friend Mr. Hixon. Our two concerns throw away over one thousand tons a day of slag. I think my average is forty two per cent. of iron, with one per cent. of nickel, and that means 400 tons of iron thrown away every day in the year.

In my experiments sulphur proved to be the insuperable obstacle. The electric furnace, appears to eliminate entirely the sulphur, so that the crude product, as I call it, might be treated in the electric furnace, and give us more iron than is made in Canada to-day.

Mr. COSTE.—In further discussion of this subject, a very important part of Mr. Evan's experiment is the fact that it seems to indicate that the manganese iron ore bodies, and the titanium iron ore bodies might be treated in that way. It is a pity Mr. Evans has not got a much larger furnace. Experiments of this kind ought to be encouraged by the Government, as they are at the present time at Sault Ste. Marie, but I think every one obtaining results as good in their small way as Mr. Evans, should

also receive substantial encouragement from the Government, especially when there are rather large bodies of titanium ores and magnetic iron sands to be treated in this way.

Dr. Porter.—In regard to Mr. Evans' paper I should like to mention the work of my colleague, Dr. Stansfield, who is unfortunately absent. Dr. Stansfield has for a number of years past carried on experiments in furnaces of somewhat the same class as Mr. Evans used, but on a larger scale than Mr. Evans. Even with his furnaces it is scarcely practicable to predict commercial results on account of the disproportionate heat loss. As regards Mr. Evans' experiments, it is extremely interesting to know that such satisfactory work was done with such small apparatus. I hope that Mr. Evans will give us, in revising his paper, estimates of his own in regard to the cost of the electrical power, and consumption and so forth.

Mr. Hixon.—Major Leckie has made the statement that we are throwing away 400 tons of iron a day in that region. We use the iron as a flux for silicious matter. It is not thrown away any more than the lime would be. There is no lime in that country and it would be a matter of hauling it in for hundreds of miles. I take exception to any statement that we are throwing away that iron. We use that iron. It is necessary to form the slag in any metallurgical process out of acids and bases. We take the bases as they exist in the ore. Regarding the utility of the electrical smelting, if the arc light or the telephone or any other invention of modern times had been discovered at the time of the building of the pyramids, I don't think it would have prospered. We have immense deposits of iron ore and it is natural we should use the things that are cheapest and nearest to hand. We don't want to go a thousand years before our time to produce things in the most expensive manner. We do it commercially on the lines of the least expense and utilize the things we have to work with, and are not going out of our way to do a thing scientifically simply because it is scientific.

Mr. Groves.—We are on the verge of a new metallurgy, and it seems to me in listening to this paper that it is of vital importance because it is the initial step with regard to electric smelting. If there is a flaw in the paper at all, it is this, that the author does not define what he means by steel. Does it mean

this, that if you have from .25 of 1% of carbon up to 2%, anything below that is wrought iron; from .25 up to 2% is steel. Now, you have no process to eliminate the phosphorus or the sulphur. When Mr. Evans speaks of steel, does he mean he gives us cast iron, or furnace iron with a little carbon, or has he taken out the manganese. Has he taken out the sulphur or the silicon and the carbon and the phosphorus; has he taken them all out, or what does he mean when he says "steel"? It is of vital importance that we should know what he means by steel. If he says "iron," and you have taken all the other ingredients out, it is a different matter. I would like to ask now, so that we, in the country, may handle these matters that you are bringing before us, scientifically, what you mean by steel? Do you mean you have only iron and you have eliminated all the other elements but that one thing?

Mr. EVANS.—I take it steel is really iron with small traces of carbon, or it is a high carbon steel. The term "steel" has been applied to so many products of a furnace, and the different kinds of steel, crucible steel, machine steel, spring steel, all of which are iron with different proportions of carbon, manganese, silicon and so on. In the titanium steels, the proportion of titanium runs up to one per cent. and in those titanium steels the silicon is very high. I have some of those samples here, which I call tool steel, which contains ½ of 1% titanium, and I put them in a small hand planer and used them in cutting iron and steel with very satisfactory results. I call that tool steel. There may be some reactions in electric smelting which do not occur in the blast furnace and which may have an important bearing on the composition and relative strengths of steel, but very little has been done yet in this direction. We cannot say what they are. I have not made any tests or analyses for manganese, and I do not know what per cent. the steel contains. Steel is judged to-day by its strength and performance under mechanical tests more than by its chemical composition.

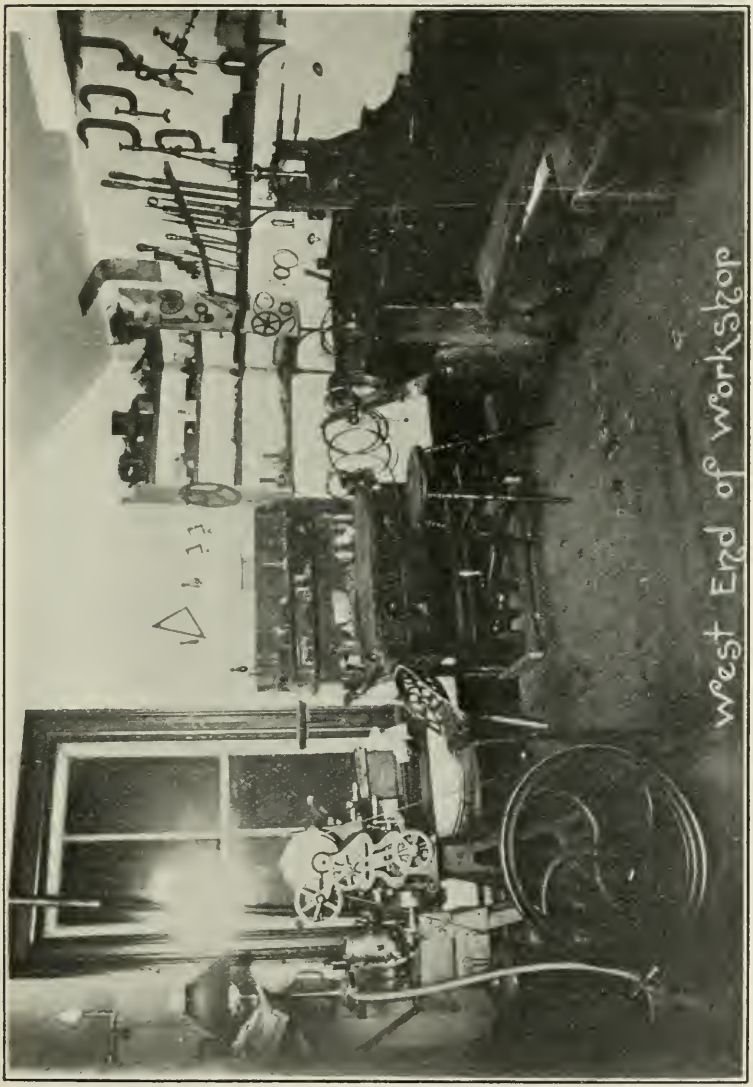

Plate I.

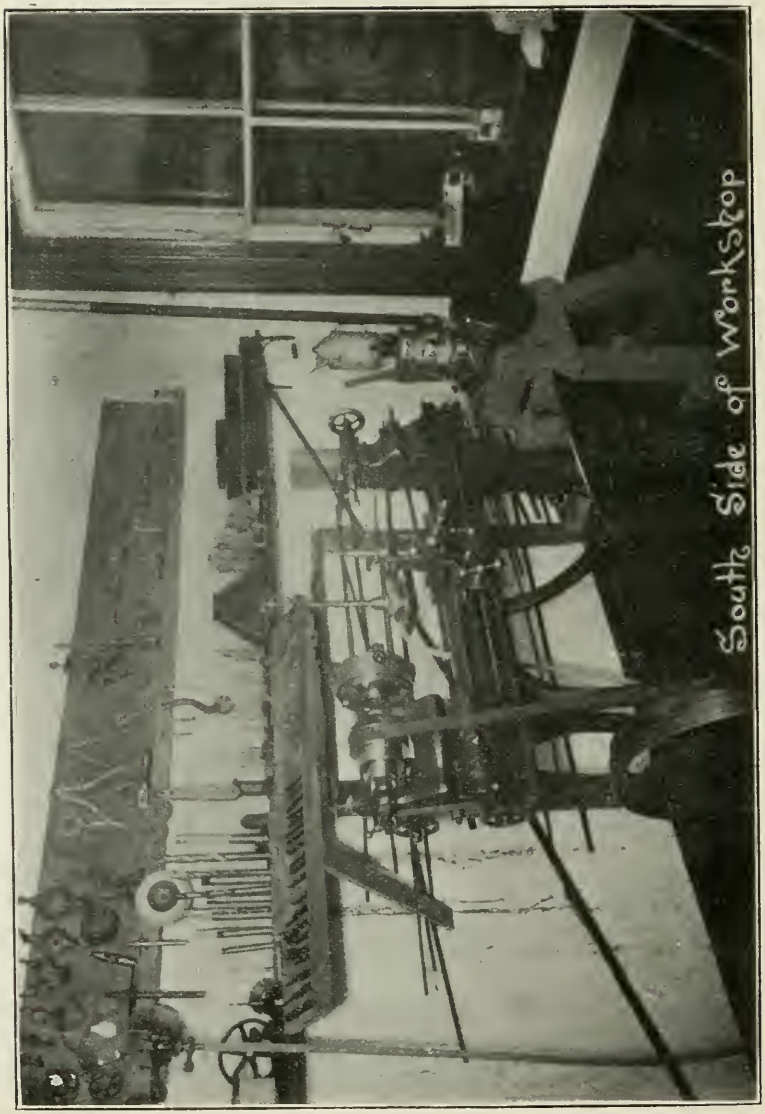

PLATE II.

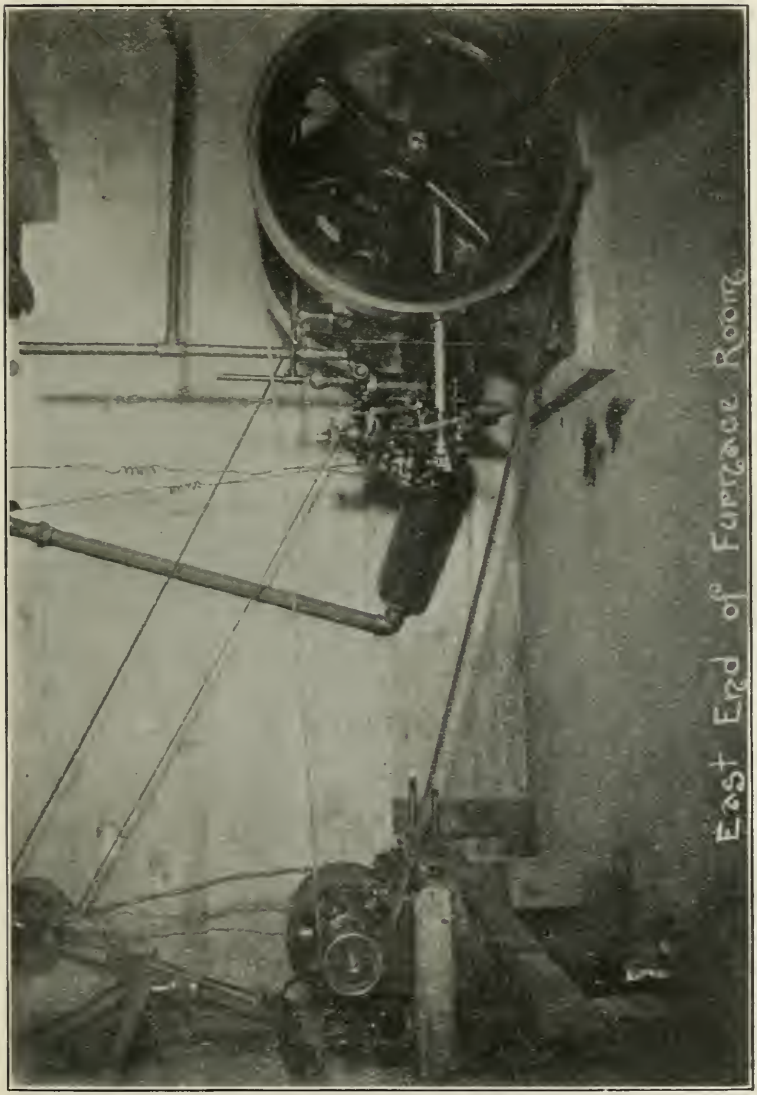

Plate III.

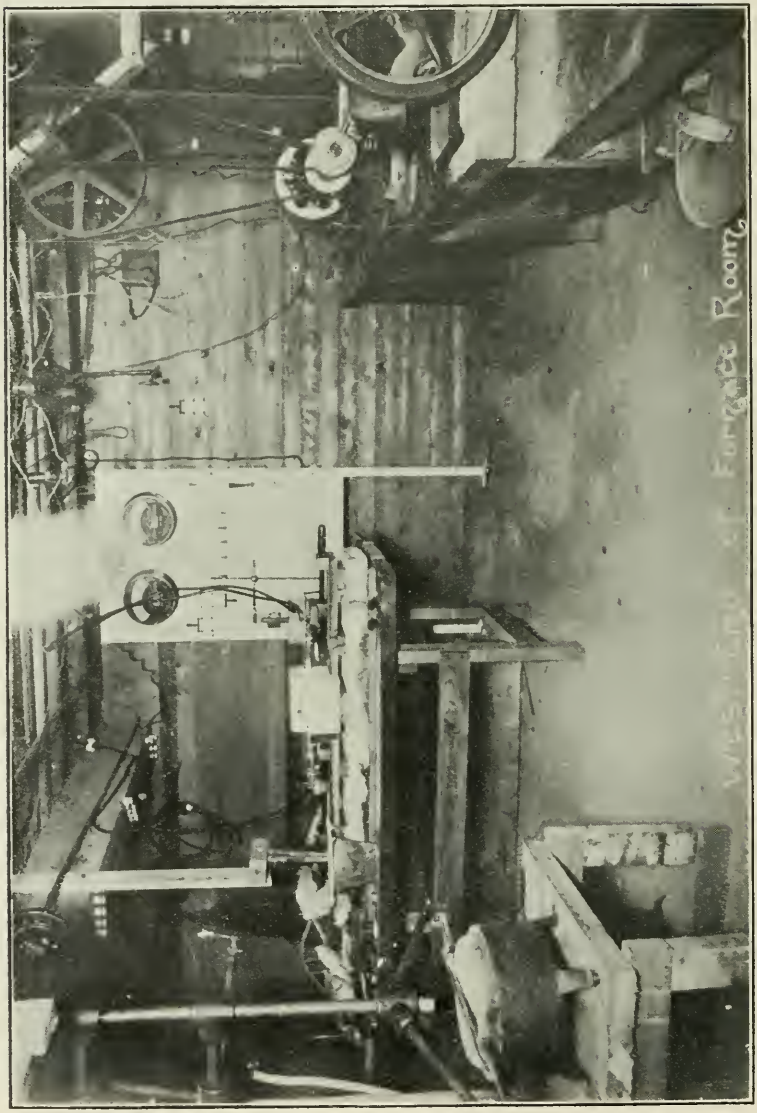

PLATE IV.

Plate V.

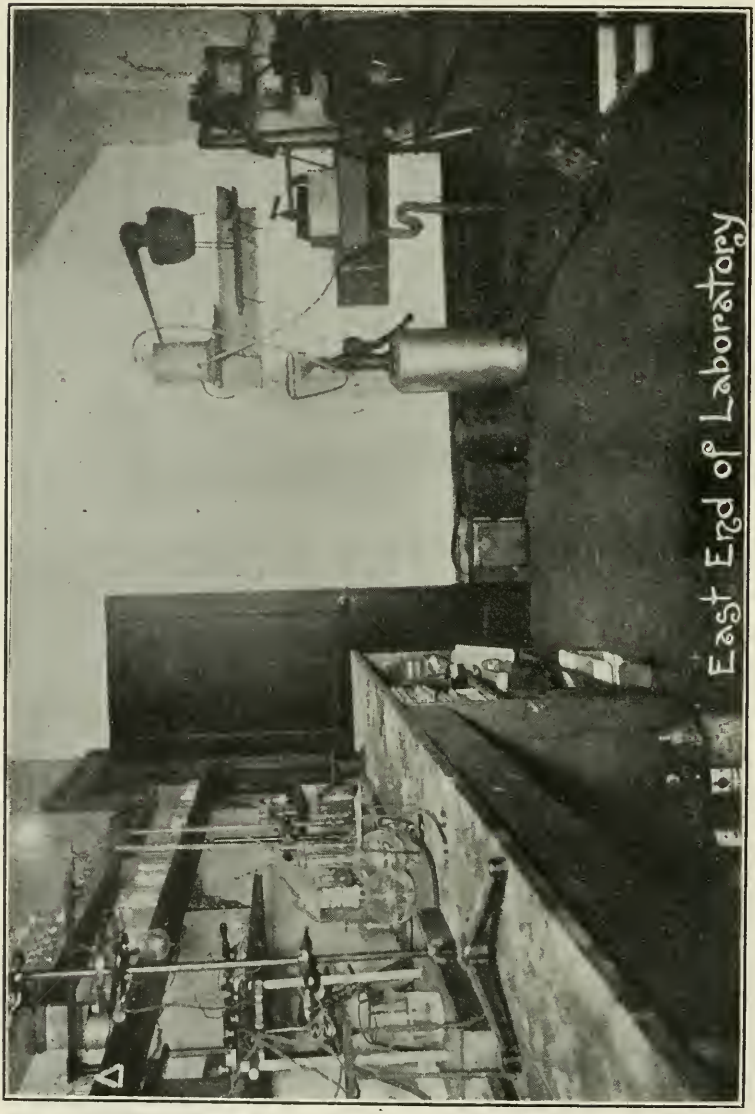

PLATE VI.

THE EDUCATION OF MINING AND METALLURGICAL ENGINEERS.

By John Bonsall Porter, D.Sc., M.Inst. C.E.
Professor of Mining Engineering, McGill University, Montreal.

Until a comparatively recent day Engineers as a body showed little interest in what may be broadly termed Engineering Education, and left it to the Universities and Technical Schools to formulate and carry out such schemes for training young men as they saw fit. There were of course notable exceptions and many Engineers of the highest rank gave invaluable advice, assistance and sympathy; but in general the feeling of practicing engineers and particularly of Mining Engineers to teachers of Engineering was indifferent and occasionally even unfriendly.

Under these conditions the natural tendency of professors to become pedantic was not sufficiently neutralized, and although the public demand for advanced education led first to the foundation of professorships in engineering in each of the great Universities, and later to the development of special faculties and schools of Engineering with elaborately differentiated departments covering the several branches of the subject; yet, in general the methods of teaching remained to say the least somewhat academic.

It is but a very few years since it was possible, and even quite a matter of course, for young men to be granted University degrees in Mining Engineering without even having seen a mine, and in other branches of Engineering the situation was no less absurd.

The so called Summer School established twenty odd years ago by Columbia University, and adopted (usually as an optional course) by several other Mining Schools, was the first and most important move in the right direction. The equipment of Engineering Laboratories, and later of special laboratories of ore dressing and metallurgy, was almost equally useful; and now every school of importance is provided with laboratories, and

offers its students so called practical and experimental courses in many branches of engineering.

These changes, and the introduction of manual and technical training in both elementary schools and colleges, have met with approval from practical engineers, and during the last few years the technical journals and the Transactions of Societies have contained a great number of papers on Engineering Education. Further, practising engineers and works managers have displayed interest in the education of young men, and have shown a far greater willingness than heretofore to admit students to their establishments and to offer employment to engineering graduates.

This general interest in technical education is most gratifying to those professionally engaged in engineering teaching and is bound to result in great good, but it is not without its danger.

The practising engineer, no matter how thorough his own education has been, usually finds little or no direct use in his practice for higher mathematics and for the pure sciences, and he fails to realize the immense part played in his own intellectual development by the study of these subjects. On the other hand he is constantly conce ned with technical detail and naturally looks with approval on any schoo! which turns out men ready with facts and figures for immediate use. His influence is therefore almost always in favor of technical as compared with scientific education.

For somewhat simila· reasons the majority of engineering students—at least in North America—are very keen to work at studies which have direct and obvious bearings on their future profession, and are grudging of time given to pure science. They fail to see why in a mining course, for example, mining itself should be assigned fewer hours of study than certain other subjects, and why all professional subjects together should occupy but one quarter of their course.

Similarly, many managers and even thoroughly educated engineers, in judging the comparative merits of young men seeking employment, naturally prefer those who have a maximum of technical knowledge and can at once be made useful, to men whose knowledge is more general.

Under these influences the engineering courses are being somewhat rapidly modified even in the more conservative schools.

As a whole the changes are for the better, but, at the moment, it is probable that in this country at least, too great weight is being given to the technical side of education. Certainly there is great confusion in the minds of many laymen and some teachers between Science and Technology. How to do a thing is taught rather than why to do it, and, in the stress and rush of filling students with facts, the infinitely more important business of teaching them to think is almost forgotten.

This utilitarian tendency is shewn most fully in the Correspondence Schools which have sprung up within the last few years and now number their students by hundreds of thousands. These schools have largely taken over the work once attempted by night schools, mechanics classes, etc. and as a whole do it admirably, but they are unfair to their patrons in that they often ignore or make light of difficulties and give their students a somewhat exaggerated idea of the completeness of their own knowledge. The young men who take these courses are rarely able to spare the time and money necessary for a University education, and what they do learn is therefore all to the good, but it is unfortunate that these schools so often fail to make it clear to the students that purely technical knowledge is after all only half knowledge, and that the highest achievements in engineering are only possible for men who are thoroughly familiar with the principles of the pure sciences underlying all engineering practice.

Technical schools and similar institutions usually occupy a position in advance of the Correspondence Schools, but as a rule their standards of admission and of class work are comparatively low, and it is left to the more conservative Universities and to certain exceptionally thorough technical schools to provide the highest type of engineering teaching.

This teaching should be in general very similar for all branches of engineering. The preparatory work should include good elementary training in the usual school subjects, in elementary mathematics and in at least one modern language. Latin is also desirable, and last, but far from least, the students should be able to write English accurately and clearly.

Assuming this preparation to be of the standard of the best Canadian and American schools, the engineering course should then take four years, two of which can be devoted with advantage

to advanced mathematics, and to physics, chemistry, geology, etc. With these pure science subjects there may be a certain amount of elementary shop work and foundry practice. Time must also be found for mechanical drawing and some sketching.

The long vacations should also be utilized in part for further shop experience in real works, or, in the case of mining students, for labourer's work underground, and for field classes in surveying.

The two final years may then be given with safety to more technical studies. Pure mathematics being now sufficiently in hand, its engineering applications to structures and machines are considered under the heads of applied mechanics and machine design. The elements of electrical and mechanical engineering are also essential to all engineers, and miners need also elementary metallurgy and mineralogy. The studies in chemistry and geology must also be extended, and laboratory work must be done in one and field experience gained in the other.

The main part of the work last outlined can be done in the third year of the course, and a portion of this year and almost the whole of the fourth can be given to what may be called "professional work," that is to say to special studies in the branch of engineering chosen by the student. In the case of Mining and Metallurgical students the various branches of mining and ore dressing and of advanced work in metallurgy may be included.

It is obvious that no very elaborate detail can be taught in technical courses which have to be carried through in a single year or at best in a year and a half, but elaborate work is not needed in engineering classes. The essential thing is to get students in the way of thinking as engineers, and to familiarize them with the general principles and fundamental problems of their profession. It would be impossible in one year or indeed in ten, to teach a student the detailed technology of the whole of his selected branch of engineering, and it is obviously rarely possible to select the particular part which he will afterward practice. It is however quite possible to give an intelligent young man a general view of the subject, and then to teach him the technology of a limited number of carefully selected typical processes, and if he knows these thoroughly he will have no difficulty later in learning whatever special processes he is called upon to use. In other words if a man is taught to think as an engineer and to work as an en-

gineer in any one branch of mining or metallurgy, he can, whenever necessary, qualify himself quickly for any other branch when the circumstances make it necessary.

In what has been said above, practical work, summer schools, and laboratory experiments have been mentioned, but it remains to discuss them at some length. The student of engineering should, at an early period in his course have some training in shop work on the ordinary materials of construction. He will not be able to spare time enough to become a skilled workman or even a half skilled apprentice, and he must be made to understand this clearly; but he can and should work long enough to know something of the use of tools, and to understand the qualities of the materials of construction which he is about to study theoretically. This elementary shop work is often carried out in work shops connected with the schools and universities themselves, and frequently can be done in the afternoons of days, the mornings of which are given to more academic studies. This method is economical of time and there are many advantages in having the teaching and shop work under the same direction, but unless a boy is to get thorough practical training later, it is better for him to go to an ordinary shop where he should be required to work full time each day under ordinary shop discipline. In no other way can he be made to realize what work really is; the intimate acquaintance with workmen is also very useful.

The shop work if done outside of the school can usually be arranged for the long vacation, which should be long enough to give time for it, and for a reasonable holiday. Two periods of two or three months each in two successive vacations should suffice for an ordinary boy, especially as practical technical training is also required at a later period in his course.

This latter technical work is even more important than the shop experience. It should, if possible, follow the general science teaching, and precede the specialisation. The students should first be taken into the mines in a body, and be given an opportunity to visit and study works under the guidance of a staff of competent instructors. After a month or two of this field work, each student should obtain bona-fide employment in some works in his chosen speciality, but the exact nature of the work is of no very great moment, so long as it is good en-

gineering, done by good workmen intelligently directed. The important thing again is to get the student in touch with real work and real wage-earners, and to give him an idea of scale. The elementary shop work may be done at convenient times in a school shop, as recommended above, but this technical work must be real in every respect. The student should, for the time being, become a plain workman on wages, responsible to his foreman for certain duties, and liable to penalty or discharge for cause.

The time to be given to this work must depend on circumstances. Three months under the right sort of foreman, in a small but interesting mine or mill, will teach as much as a year of ill-directed drudgery. Furthermore, students differ greatly in the readiness with which they take to practical work. Some are the better scholars for having had many years of hard apprenticeship; but very frequently the man who has spent even one year in practice finds it difficult to return to his classes. He is earning money at work, and can often ill-afford to give it up, and again become dependent on his people. Study also often proves irksome, and sometimes very difficult after a man has been actively employed. As a result, many men fail to return to their final studies, and thus lose what should be the most useful part of their education.

If a definite time for practical experience must be set in advance, it is probable that two periods of about four months each in different establishments, or one period of a year would be about right; but in this, as in all other matters of technical education, it is far better to make the regulations somewhat elastic in respect of field work and advanced study. Much time can be saved the students, and their training made more effective, if each case is separately considered by the responsible head of their school.

This last and most important period of practical training should follow the elementary engineering studies, and if possible come between the third and the fourth year in a four years' course. From it the student comes back to his school with fresh enthusiasm yet without having got out of touch with academic methods as he would have done had he spent a longer period at work. He now enters on his advanced study and the teaching may be highly specialized and quite technical, but care must be taken to keep fundamental principles in sight, and the detailed technical work

should be carefully laid out to cover only certain important typical operations. The academic work can be made much more interesting and effective by the free use of technical laboratories, in which engineering machinery (and in our case ore-dressing and metallurgical apparatus) can be used; but here, as in the lecture room care must be taken to teach principles, not processes. Certain processes must of course be used, and a good deal of careful detailed work done; but the primary purpose must always be to teach general principles, and mere technology must be kept in a secondary place.

The best function of laboratories, aside from the limited use necessary to illustrate fundamental principles, is to develop the initiative of the students. Each man should be given certain carefully selected pieces of independent study, and should be encouraged to attack his task in his own way. One or two comparatively heavy investigations are more useful than many short experiments, and the instructor in charge can often do his men far more good by showing interest, and yet letting them work out their own salvation whenever possible, than by being too ready to set up apparatus and smooth over difficulties. This advanced individual work can utilize to the full the resources of even the most magnificently equipped laboratories; but care should always be taken especially in schools which are very rich in practical apparatus, to see that the students should do a few things thoughtfully, and with a clear apprehension of their bearing, rather than that they should get shallower experience of many processes and machines.

In connection with this advanced study the men should be taught to write up their results, and to apply the knowledge gained in works, laboratories and lecture rooms, to some practical problems in engineering. In these, questions of estimates and costs should be considered, for the men are now about to go out into the world where costs form an essential element in every enterprise. Estimates made even by advanced students are likely to be far from right, but their preparation gives the men extremely valuable experience, and a competent instructor can do excellent work by discussing economic matters with his men in this stage of their training.

This should end the school course in engineering, for no

amount of mere teaching will turn a boy into an engineer, still less into a mining engineer. If, however, he is given a good grounding in science and the principles of engineering, is then put in touch with practical engineering work, and is finally taught the elements of the technology of his subject, he will be prepared as well as any school can prepare a man to go out into the world and learn to become a good engineer.

Such a course of study as has been outlined above is very different from the old-fashioned course in Mining, and in fact is different in some respects from any course in Mining offered at present, although many schools approach it, and each year sees changes made which bring our science courses closer to this ideal. In this connection the author takes the liberty of briefly outlining the course in Mining and Metallurgy offered by his own University, not because he believes it to be by any means perfect, but because it illustrates very well the modern practice in engineering teaching.*

At McGill University students are required when entering to show a good knowledge of mathematics, of one modern and if possible one ancient language, and of the usual English and general subjects of the higher schools. They then devote their time for two years to advanced mathematics, physics, chemistry, elementary mechanics and surveying. They also give a great deal of time to drawing and to shop work. In addition to their studies in the University they are required to do one month each year of extra mural-work in surveying.

Up to the end of the second year, all engineering students take the same course; after that differentiation begins, mining and civil engineers giving more time to surveying and surveying field work, while electrical and mechanical engineers spend additional time in the drafting rooms and machine shops.

In the third year in the Mining and Metallurgical courses, lectures are given on the elements of mining, metallurgy and ore dressing, and final work is done in the more general engineering subjects.

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*The illustrations accompanying this paper need no description beyond that printed on the plates. They are chosen with a view to illustrating the character of the Ore Dressing and Metallurgical laboratories alone and do not by any means cover the whole equipment of the department, much less of the school as a whole.

At the end of this year the class is taken to the field and five weeks are spent in studying mines and metallurgical plants under the personal direction of the staff of the department. The district visited is carefully chosen with a view to offering the students the best possible opportunities for observation, and the method in general is to first spend ten days or a fortnight in one particular mine or works, thus familiarizing the students with the plant and making them quite at home in it. The remainder of the period is then spent in visiting other works, one or two days being given to each, and the differences in method, etc. noted and studied.

During these excursions, which are ordinarily carried out in a private car chartered for the purpose, students and staff live together, and informal lectures and discussions are held whenever practicable, in order to call the attention of the men to salient points of interest.

While this class work is going on arrangements are made with the managers of the plants visited to take on individual students for the remainder of the summer as workmen. In this way it has always proved possible to provide employment for all men who have not already secured engagements for the summer, and at the end of the field school the class disbands, not to play for three months, but to go to remunerative individual work.

On the return to the University in the autumn the detailed technical and laboratory work already referred to is seriously begun.* Certain typical operations are performed by the whole class, such as a stamp mill run, the concentration of a lead or copper ore, and a short campaign with a copper or lead blast furnace. The main work of the succeeding six months is however individual and each man is encouraged to take up same investigation which is especially interesting to him, such as the concentration of the ore from some mine in which he hopes to obtain employment, or the smelting of a particular material, etc. This individual study is under the eye of competent instructors, and assistance is given when needed; at the same time, and, when possible, in the same connection, he is required to design

*In the appendix will be found a copy of the instructions given to students at the beginning of their elementary work in ore dressing. The more special advanced work is similarly covered wherever possible by instruction papers which need not be repeated here.

work as and to prepare approximate specifications and estimatse as already outlined.

In a recent paper by Dr Stansfield* the method of laboratory teaching in Metallurgy is admirably set forth in detail. The method employed in the Mining and Ore Dressing Laboratories is so similar that it need not be more fully described here.

The University course thus closes with a year of work as practical as possible, yet so laid out and directed as to be theoretical as well, and at its end the student is sent out to begin the practice of his profession. His education is however but half over, and if he wishes to achieve high success in the end, he must content himself with a subordinate post for many years, and work hard and patiently to master the details of his special business, to learn to command men and to know himself.

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LABORATORY NOTES ON TRIAL RUNS IN ORE DRESSING.

Department of Mining Engineering, McGill University.

With some ores it is so simple a matter to separate the constituents, that a competent engineer needs only to examine the material and have it assayed in order to determine upon a fairly satisfactory scheme for concentration.

With the majority of ores the case is, however, very different, and the engineer can by mere inspection do little more than decide upon the general features of schemes that will probably be effective. In such cases it is very desirable that these schemes be tested and developed by means of experiments on a small scale, before any extensive tests are made, and still more before actual plants are designed and built.

These small scale tests can sometimes be carried out with very simple tools such as the hand sieve and the miners' pan; but usually it is best to use more elaborate apparatus, and to attempt the actual work of concentration on a laboratory scale.

Such experiments, if properly carried out, are frequently of the greatest value, not only in testing the proposed scheme, but also in bringing out the individual characteristics of the ore under examination, and in determining many details of treatment.

It is, of course, unreasonable to expect such tests, or laboratory tests on any scale, to determine every part of a complex scheme for commercial treatment, and many adjustments, and even important changes will have to be made after the final plant is built and in operation; but in the meanwhile, the test is invaluable as an aid to the designer and engineer.

In the following pages a somewhat comprehensive scheme for testing is set forth, but persons using it must remember that any general method no matter how carefully drawn up, will apply imperfectly to any special case. Students will, therefore, be expected to use their own judgment and to follow the spirit rather than the letter of the instructions.

Sample.

The Purpose of the test is, first, to determine the method to be used, and, second, to approximately determine the details of the apparatus required, and the probable results of operations on a large scale.

Sample. Secure a representative lot of the ore to be tested. If at the mine, this should be taken from the working places in a systematic and impartial manner, to represent the average output of the mine under working conditions.

Sometimes it is desirable to test some part of the mine, or some product as for example the low grade ore left after the removal of specially rich ore which is sent direct to market. In such cases the sample should be fairly chosen with a clear understanding of the end in view.

The sample should, when possible, weigh at least a ton, and often many times this amount should be taken. In this connection it is not enough to consider only the amount required for the proposed tests. As a general rule ores containing high grade mineral are more irregular than low grade material, and therefore larger quantities are needed to secure a fair average lot, even if only part of the lot is afterwards needed for the test proper.

If it is impractible to sample the mine as above, every effort should be made to secure a representative lot of the ore, and in this connection it must be remembered that it is almost as bad to have the sample too low in grade as too high.

Care should also be taken to get the ore in about the condition in which it would normally come from the mine. There should not be an undue proportion of fine or coarse ore, and there should be as much gangue and wall rock as would be likely to get in in ordinary mining.

PRELIMINARY EXAMINATION.

A small average sample of the main sample should be taken and carefully examined to determine the constituents minerals and their relations to one another. Note especially the size and shape of the individual grains of the valuable minerals and decide upon some size above which reasonably clean separation is obviously impossible.

Then crush a portion of the sample to this dimension and size it on a nest of sieves. Examine the coarsest size, then the next finer, etc., until one is found in which the majority of the grains are free

The proper size is one that will free a good proportion of the grains and yet will not crush them more than is necessary. It is better to leave a moderate number of inclusions along with the freed grains, than to crush a large amount of free material too small. The inclusions can usually be separated as a middle product and specially crushed and treated again, with less loss than follows the undue sliming of the whole lot. Not infrequently an ore will be found in which none of the coarse particles are sufficiently free from valuable mineral to be wasted, while some are so high in grade that further crushing is undesirable. In this case the coarser sizes should be jigged for coarse high grade heads, and both the middles and tails obtained should be recrushed separately or together and treated again.

In the above instructions it has been assumed that the mineral grains are all comparatively small and disseminated through barren or low grade rock. This is true of concentrating ores proper, but often the original sample will contain some comparatively large pieces of pure or high grade material. When these are over an inch or so in diameter, it is expedient to subject both the preliminary and the main samples to hand sorting.

Hand sorting is rarely practised out of the laboratory on material that will pass through a sieve with one inch openings, and ordinarily the limit is two inches or over.

All stuff finer than this is ordinarily crushed and concentrated, but the coarse stuff should be examined for the following grades of material.

(1) Pure mineral and mineral so rich that it is already fit for the smelter or market, should be picked out and set aside.

(2) Rich concentrating ore, or ore with special constituents which require special treatment, should be similarly set aside and separately tested.

(3) Barren material or ore of very low grade should also be set aside.

(4) Average concentrating material which remains should be added to the fines.

The lots thus specially selected should be weighed and then sampled, and the results noted.

Note.—In laboratory tests hand sorting is often done on stuff down to ½-inch or even smaller, when there are difficulties in the way of jigging small lots of material of this size.

Crushing and Sizing of the Main Sample.

After the preliminary work is finished, the main sample should be carefully mixed and quartered, and a portion of sufficient size for the final test taken. The amount required varies with the circumstances, but may be taken roughly at from 5 to 25 lbs. for a field test with sieve and pan, and from 100 to 300 lbs. for a laboratory test with small jigs and tables. In any case it is expedient to have an ample quantity.

This portion should be weighed and roughly sized for hand sorting as per the instructions given above, and then should be crushed to a size a trifle larger than that decided upon in the preliminary work as giving a fair separation. If this crushing is to a small size it should be done in stages with intermediate screenings.

Any available crusher may be used, even a spalling hammer, but it is best to use a machine of the type that would be used in practice.

The crushed rock should then be screened into as many sizes as are likely to be necessary: (the scale of reduction depending on the specific gravities of the minerals to be separated).

The portion under 1 m.m. or better ½ m.m. need not be sized as it will have to be classified. In fact in mills the minimum is usually over 1 m.m.

The weight of each size should be taken and with it a note made of the appearance of the material. Then each size should be jigged.

Classifying.

Classification in rising currents may be used for comparatively coarse material, but is usually desirable only for the stuff under 1m.m. A small portion of this material should be tested in a small tube classifier, and current velocities determined that will divide it into, say, four nearly equal classes. The whole portion of fines may then be treated in a larger Richards or Munroe Classifier set successively for these several velocities.

The best method is to set for the minimum velocity first, and catch the fines in the overflow. The coarser sorts can then be readily separated by successive treatments with increased velocities without further diluting the slimes.

The several products of classification should be kept separate, and subsequently treated; the coarser by jigging, and the finer by vanning; but each should first be sampled, and if convenient dried and weighed.

Note.—Trouble is frequently caused by the tendency of fine dry stuff to float when first put in water. It is therefore expedient to wet the whole lot before attempting to classify it. To do this, place the fine material in a sieve or sack and stand it in water deep enough to almost cover it. The lower part will at once become wet, and capillary action will soon carry moisture to the topmost grains.

JIGGING.

Jigging may be done with either a small hand sieve or with more elaborate apparatus such as the Vezin laboratory jig, or the larger two compartment jigs recently built. The former demands considerable skill on the part of the operator, and at best usually gives less exact results than a power jig, but it has the great advantage of being always available even in the field.

Hand Jigging should be performed on sized stuff, each size being treated by itself. The mesh of the sieve should be smaller than the smallest grains treated on it, except in special cases where it should pass the finest but hold the coarsest part of the material.

The sieve should be filled about two-thirds full of the coarsest sized stuff and jigged under water for several minutes. The stroke should be slow on the rise and quick on the descent, and great care should be exercised to avoid any side throw. In some cases the jig may be raised enough to partly emerge from the water. This increases the suction and tends to draw the smallest grains to the bottom. The operation is, however, difficult to perform, and is only useful in special cases. For coarse stuff, the stroke may be long and slow. For fine it should be quick and short.

After jigging for some time the surface of the sand will show clean tails. These tails may then be skimmed and new ore added and jigged. This operation must be repeated until a sufficient quantity of heads and middles have accumulated in the sieve, or until the whole of the portion of the ore has been used. The sieve must be carefully skimmed at the end, and the portion too rich for tails and too poor for heads set aside as middles. Each of the three products may require rejigging or panning by itself to make it sufficiently clean.

Each size of the test sample should be similarly jigged and the products kept separate.

Usually some fine stuff remains in each size and passes through the jig sieve, some fines are also formed during the operation; these fines, if rich enough, should be added to the heads or middles, but if too poor for that, they must be added to the next size finer, and treated again with it.

Machine Jigging is performed in much the same way as hand jigging, but the mechanical devices make it possible to do more accurate work. Laboratory jigs are rarely provided with quick return mechanisms, but it is usually possible to adjust the water supply in such a way as to give the effect of either quick or slow return.

The coarsest stuff should be jigged first, with long slow strokes, and ample water in the piston compartment (pulsion). The bed of material on the sieve should be about three inches thick, and after it has been jigged until the surface shows clean tails, fresh material should be fed slowly and uniformily. The surplus tails overflow automatically into a tank, and at the end any remaining tails are skimmed and added to them. The middles are then skimmed, and next the heads and each saved. If the middles fill the sieve and begin to come over before the end, the jig should be stopped, and part of the accumulated heads and middles removed.

At the end each product may have to be run again by itself to get it clean.

The fines which pass through the sieve into the bottom box should be flushed out at the end and either added to the product already made or re-treated with a finer size.

Each size should be jigged as described above, with the difference that the finer sizes require shallower beds and shorter and faster strokes. Less underwater is needed also, and for very fine sizes very heavy suction may be obtained if necessary by feeding water with the ore and permitting a constant escape of water from below the sieve.

This last device in combination with the use of the stay box makes it possible to jig very fine stuff such as the coarser sorts from the classification of the material too fine to sieve.

Jigging through the bed is sometimes successful even with hand sieves and coarse sizes, although the methods already described are better adapted to most ores. With fine stuff and machine jigs it is frequently desirable, and in test work with very fine stuff it is almost always expedient to use this method.

The sieve must be selected for each size and must pass the greater part while it retains, say, one third or one quarter. The stroke should be short and quick and the water adjusted to give strong suction.

After a good bed of concentrates has accumulated on the sieve, work should be stopped and the bottom box cleaned out, and its contents mixed with the stuff remaining to be fed.

On resuming work the throughs should contain little or nothing but pure heads, and work can be continued until middles or coarse concentrates come over with the tails.

By using a stay box or a two compartment jig the middles can be saved without frequent skimming.

Occasionally it is practicable to get really continuous work, by using a sieve of such size that everything can go through. In this case a bed of coarse mineral is secured (usually from the next size larger) and put on

the sieve before starting, and if necessary additional mineral is fed from time to time.

This method is too complicated for most tests, but is occasionally useful as a means of securing a large and uniform output from a small jig.

VANNING.

The finest class of slimes from the classifier, and often one or more of the classes next coarser than this, are too fine to be jigged and must be concentrated by vanning. This may be done with considerable accuracy in the pan or batea, but when practicable it is expedient to use a laboratory slime-table.

Vanning with the Plaque is done on comparatively small portions of material. The plaque is held firmly with both hands and partly filled with water. It is given a slow downward and forward motion of half or three quarters of an inch, followed immediately by a quick upward and backward jerk; the plaque being meanwhile held slightly inclined. This drives the heads up the inclined surface of the plaque, and by repeating this operation they may be separated from the other material. The plaque is then given a slow gyrating motion which lifts the tails while disturbing the heads but little. This sweeps some of the tails over the edge of the plaque.

By alternating these motions the tails can all be cleared from the plaque, but it is best to van them again and add their heads to those first obtained.

The material must be kept wet to avoid float, and must be kept in motion to prevent packing.

By repeating the operations and weighing and assaying the products, it is possible to get surprisingly accurate results.

Another method of using the plaque is to hold it in one hand, as one uses the horn spoon, and strike it on the edge with the other hand, thus getting a bumping motion. This is less effective than the method first described, but is easier to learn.

The Pan may be used for larger quantities up to say 10 lbs, per charge. It is scarcely as accurate as the plaque or batea except on very heavy minerals.

The pan is filled, immersed in water, and the contents gently but thoroughly mixed. The pan is then raised and gently shaken to level and settle the contents, none of which may yet be permitted to waste.

The shaking should be gyratory, with occasional short, sharp, forward, backward, and side shakes, and should continue until the contents are well settled. The pan may then be inclined four to eight degrees, held with two-thirds of the rim under water and given a horizontal elleptical movement, the forward motion being slow and the return more rapid. Water flows in on the forward stroke and escapes on the return carrying sand with it.

This motion may be repeated five or six times, and then must be followed by settling as above after which a little more sand may be washed off. By alternating these operations the heavy pulp can be kept settled while the tails are being removed. If the work is carefully done, a very clean con-

centrate can be made. The tails often carry too much mineral and must be repanned.

Vanning on Tables.

Small slime tables seldom do as perfect work as tables of full size, and whenever the quantity of pulp is sufficient it is best to treat it on standard Wilfley, Bartlett or Frue machines. Small quantities of pulp cannot however be successfully treated on these large tables, and a number of special tables have been designed, modelled upon the larger ones, but differing in minor details. The best of these small tables have riffled surfaces and are in general similar to Wilfley or Bartlett tables.

The following general rules should be observed in using these tables. If more detailed instructions is needed in any case it should be sought in the notes on the special device to be used, such as the Wilfley, or Bartlett table, the Frue Vanner, etc.

(1) The mechanisms should first be adjusted to give a short stroke, with slight but unmistakable quick return or bump. The speed should be moderate, say 300, and care should be taken to prevent any lifting of the table, which should work smoothly on its bearings.

(2) The table should then be given a moderate slope and the wash water and feed water turned on and adjusted to give an even flow.

(3) Provision should then be made for catching the products of the table without any loss.

(4) Pulp may then be fed slowly and evenly, and its course carefully observed. In all probability some separation will be at once evident, but it will be far from satisfactory, and it will be necessary to change one or more adjustments, with a view to effecting a clean separation and to sending the several products to their proper places.

(5) These adjustments are as follows:—

Change of slope of table.
Change of quantity and distribution of wash water.
Change of quantity of feed water.
Change of quantity of pulp fed.
Change of speed.
Change of length and character of stroke.

These changes should be made one at a time, and their effect observed until a fairly satisfactory result is obtained. The several products should then be critically examined on the vanning plaque and final adjustments made.

(6) Note should be kept of these adjustments, and of the conditions of water, slope, speed, etc., finally adopted.

(7) The products of the table during its adjustment should then be collected, mixed, the surplus water run off, and the pulp returned to the feed and treated again. The products of this run must be kept separate, weighed and assayed.

(8) Sometimes it is impossible to make clean products in one operation on small tables. In such cases, the best work possible should be done, and then each product needing it should be treated again alone. This is quite legitimate, as the distance travelled by pulp on a full sized table is from three to ten times that on a small machine.

(9) After one product from the classifiers has been treathened text, should be attempted, and it will usually be found necessary to change the adjustments before good work can be done. These changes should be carefully studied with reference to the difference in size of the particle treated.

Special Work.

The operations above outlined (sorting, crushing, sizing, classifying, jigging, and vanning), comprise the ordinary work of ore dressing, but there are many cases where additional, or special work is required. It is unnecessary even to give a list of the various special cases which may arise, but a few of the most important may be named as follows:—Amalgamation as applied to ores of gold and silver, Magnetic separation as applied to a great number of substances, Oil Concentration, Pneumatic Concentration, Heating followed by some operation not previously effective, etc., etc.

Samples, Assays and Records.

In order to make full use of the work done in tests of the kind outlined above, it is necessary to keep records of every detail of the operation, and every product, intermediate and final, must be weighed, sampled, and if necessary assayed.

In many cases, certain of the products may be sufficiently examined under a lense or microscope, others and sometimes all can be approximately tested by fine grinding and vanning on a plaque, but in all work of importance it is essential to assay all the chief products, and sometimes every sample should be carefully assayed

DISCUSSION.

Dr. Douglas.—Though, to my great regret, I have not had the advantage of a technical education myself, I have had a great deal to do with those who have had it, and in some respects my ideas are very clear as to what a technical education should be and what it should not be. I agree with the main principles laid down by Dr. Porter. The technical school should not waste the time of its pupils on antiquated methods, nor should they lay too much stress upon present methods. Furnaces change

both in character and size from year to year, and we should not load up the student's memory with what, when he enters on the actual practice of his profession, he finds more difficulty in forgetting than he ever had in learning. The professors should teach fundamental principles as far as they know them, and forebear from loading up their pupils with a multitude of details which, when they enter actual life, clog their usefulness rather than add to it.

As a rule an academic course is not considered a necessary preliminary to a technical course. Yet where the technical school is an adjunct to a university, the technical student should take advantage of some of its academic facilities, for I am certain that the technical student should give greater attention to the cultivation of his literary faculties than is generally bestowed on them. You all know how seldom you come across a scientific book that has any literary merit, or that is written with even the ordinary literary skill which enables an author to express intelligently what is passing through his own mind. In fact, a great deal of scientific literature is as puzzling as the poetry of Browning. Now, whether we expect to be authors or not, we are sure to be called, in the practice of our profession, to write reports, and I have known a well-written report to be the first step in the successful career of a mining engineer.

To the student there is no exercise more beneficial than carefully writing down his conceptions of any subject. When he reads what he himself has written, he only then becomes aware how imperfect and hazy is his understanding of the subject, and how rambling his thoughts upon it are. It is undoubtedly presumption on our part to offer to the publisher much which we write, but whether he accepts it or not, or whether the public ever reads it, should he accept it, if we have any sense of responsibility, we try to think more precisely and to express more carefully what we have to say, when our written words are likely to be printed. But apart from the morality of writing for publication, the student ought to be required to explain in written theses the subjects taught, and the literary style of these theses should be as much the subject of criticism as the accuracy of his facts or the relevancy of the conclusions de draws from them.

With regard to the extent to which technical education

should be carried, I quite agree with Dr. Porter. Fundamental principles primarily should be taught. The application of those principles, however, should be explained; but in describing methods and mechanical or metallurgical appliances, it should be understood that they are merely temporary applications of principles, which are sure to be displaced by better. Therefore the student should be warned against a bigoted adherence to old or new practices, and encouraged to exercise his imagination and inventive faculties, for if he goes out into the world, he is sure to come face to face with new conditions, which adherence to scholastic precepts and historical processes will often not help him successfully to master. But while I think that a great deal of the so-called practical work in college laboratories is worse than useless, such as running a little furnace for a few hours on a well compounded charge, if it leads the lad to imagine that his experience under such conditions fits him to run a big furnace on a refractory charge day in and day out; concentrating machinery is the best apparatus with which to illustrate the principles of falling bodies moving in a resisting medium, and laboratory practice alone can train the student to use his fingers adroitly in response to his brain. Without manual dexterity he will never make a good chemist or handle adroitly delicate instruments like pyrometers. A man who can take the temperature of furnace gases, the temperature of the different zones of your furnace, measure the heat that goes to waste in your gases and in your slags, express the whole thing in clear language, and in graphic curves, and thus inform you of what has happened and tell you intelligently what he thinks will happen, is an acquisition which you rarely come across; and when you do find him you value him on that account all the more. And yet every student who leaves a technical college where he has been encouraged to think for himself rather than to simply recollect what other people have thought, should turn out in practical life just such a useful and invaluable individual. Unfortunately there are comparatively few men who, as they come out of the schools, have acquired, not only the habit of wishing to investigate all the phases of the processes they are conducting, but have acquired the knack of making nice determinations and the higher faculty of drawing sane and correct conclusions from them. This is where imagina-

tion comes in, and anyone who is to rise in his profession must be endowed with this faculty to an eminent degree.

Every student should look forward to being more than a mere employee at so much per day, yet so far as my experience as a general manager goes, I do not want to have a very technical man as a general superintendent. Looking at the position of a general superintendent from a general manager's point of view, I want a man who is a thinking machine, and not a mere piece of machinery. He should be a man who knows enough about everything to know that his technical subordinate is doing his work, but he should not himself be so wedded to any one technical branch that his eyes are absolutely closed to everything that is going on about him except the one branch which is the principal subject which he has studied, and to which he is so passionately attached that he cannot attend to anything else. I think, therefore, that the best general superintendent is a man of very wide technical knowledge, but not of too precise technical knowledge with regard to any one subject. Of course no man can start upon his technical education and say "I am going to be a general superintendent, and therefore I do not want to know anything in particular but everything in general." But he will have to find out later (or someone will have to find it out for him) whether he possesses that peculiar qualification or whether he does not. While I may not select as general superintendent a precise, technical man, at the same time the technical man that commands a good position and a high salary, whether as metallurgist, electrician or as mechanical engineer, is always the man whose profession is dearer to him than his life, who never counts his time or weighs his labour by his remuneration, but works for love. He will never need to strike for higher wages, for they are always advanced before he thinks he deserves a raise.

Mr. Hixon.—I cannot add very much to what Dr. Douglas has already said. It quite agrees with my experience. Regarding methods of teaching, that is altogether a matter of personal magnetism. Some men can go into the chair and teach a room full of students and keep them going at top speed all the time they are in his presence. You put another man there and he cannot do anything with them. Then again, it is a question of the individuality of the student. Some students can learn

very rapidly and others are scatter-brained and interested in things other than what they are being taught, and they don't acquire information easily, so that the problem is altogether too complicated to lay down any hard and fast rule in regard to it. I remember in my own personal experience listening to the lectures of a man in metallurgy whom I respected very much, and from whom I could acquire information very rapidly. After a time he got an outside practice as consulting engineer and substituted a young graduate from a college to undertake his professional work; but this gentleman was quite incapable of concentrating the attention of the students on the subject in hand. He read out of books to them, for his information came from book knowledge and not from practical experience. We had no respect for his abilities, and the result was the whole work became disorganized and two years later the professor, who was very competent, and who could have carried it to a point where it would have had a national reputation as an educational institute, was asked to resign and the school was disrupted. Now, the point is this, if a man is to be a teacher or a professor in an institution, he must devote his time to it and leave outside interests alone. He cannot combine successfully education and commercial business and consequently a university professor should not undertake professional work of any kind.

Mr. DARU.—I agree to a very great extent with what Dr. Porter has said, but there are a few things on which I wish to lay special emphasis and to which I wish to draw your attention. I believe a student should spend some part of his time at mines, and I believe it also necessary that before a student is sent to a mine, he ought to have received a short and elementary course on the principles of mining; and he should also receive some instruction in geology and in mineralogy. Again, instructors at colleges and schools should keep themselves informed concerning the commencement of new operations, and they should send their students to see how such work is carried on. A student may learn much in this way.

In the last two years of the college course the student should be taken by the instructors, to mines in operation, as there are certain things which can only be learnt by studying a mine in actual operation, and with the professors on the spot, sufficient

instructions may be given to enable the student to carry on systematic investigations. The students should be able to work out the cost of any mining operation, so as to be able to say how the costs are apportioned with different kinds of work, and what the final cost will be.

Dr. Douglas.—With regard to costs, I think the mine manager ought to have a thorough knowledge of book-keeping, of course; but when a visitor goes to a mine the last thing he ought to talk about is cost. We are perfectly ready to give every possible facility for the students to learn our methods, but when it comes to a question of cost, that is a matter upon which the executive office only can give information. It is indiscreet; I won't say it is verging upon being rude to ask any questions about cost at all. I think we must all feel that when the courtesy of the works are offered to students, the first thing they ought to be taught is that they should never mention the question of cost.

Mr. Daru.—I don't know whether Dr. Douglas refers to what I said, but if he does, then I think I ought to make a certain explanation. I did not at all mean to say that the students should make any inquiry about costs. But I say, if the professor is on the spot with them, then he can point out to them the certain factors relating to the costs. There are many small ways which would not occur to them. Although you might not ask directly about the costs, still there are patent things before you when you are on the spot; for instance the wages paid to certain people. You can very easily ascertain these things. There are a number of other questions you can put. I always believe there are a number of sources from which you can get information; and I think if anyone wishes to become a successful mining engineer, he ought to acquaint himself with the methods of obtaining information from sources, which are not forbidden to you, but which by merely shutting yourself up in a laboratory or room you are not able to make yourself familiar with.

Dr. Porter.—As one or two matters have been brought up in criticism, I should like to say a word. Dr. Douglas and Mr. Daru spoke of the question of costs. The instructor of a field class is in a rather delicate position. I have, for ten years, taken my students annually to visit works, and I fully appreciate the statement of Dr. Douglas with regard to costs, and I try, in so

far as in me lies, to meet that difficulty by informing my students in advance that we are the guests of gentlemen who will do anything for us, but who cannot, in justice to their shareholders, give us much information on the matter of costs. On the other hand, the student, who is put through college, and sent out into the world without having learned something about the size of a dollar, is likely to prove a useless man. My principle has been to tell the students to learn what they properly can in regard to these matters, and before they write their reports, which come to me in confidence, to obtain from the management, such information as they can. The cost of many things about a mine or works need not be kept secret and in general I have found managers very ready to give students costs and figures of output so long as certain items in which there is competition are scrupulously omitted. At the present moment I have many reports from students, which the managers of works have permitted those students to hand me on condition they would go no further, but I also have other papers that the managers have allowed to be published. We try to recognize the importance of discretion and courtesy in making enquiries, and when mistakes are made, as they occasionally will be by students, I hope that managers will understand that after all the students have not had a very large experience in the world, and sometimes they are indiscreet, or perhaps, even discourteous without intention. In my experience mistakes of this sort are rare and when made they are done in all innocence. With reference to the confidential reports, everything we can do is done to prevent the disclosure of such secret information as is gained by our students in works.

Mr. Daru has also spoken of the importance of giving the students instruction in mineralogy, etc., before taking them into the field, this and other criticisms apply to my abstract of my paper, but he will find on reading the paper in full that we are pretty well agreed as to these matters. With regard to having the instructor with the men at all times to explain matters I have, however, come to the conclusion that it is often better not to be too ready with an explanation if the student can think the thing out himself. He will remember far better if he has overcome his difficulty without too much assistance.

Mr. Hixon spoke feelingly of the professor who neglects his

class in order to take outside work. He is quite right in saying that a teacher must devote his time to teaching regardless of outside consideration. It is, however, undesirable for teachers, especially of technical and engineering subjects, to get out of touch with their profession, and I think the best work is done by teachers who have had professional experience before undertaking teaching and who are able to do a certain amount of consulting or other professional work in their holidays. It is a difficult matter however, and of the two evils, the earnest but narrow or unpractical teacher is better than the man of business who makes use of a professorship as a means of securing professional or expert engagements.

I want, before sitting down, to thank the several gentlemen, who have discussed the paper, and particularly to express my very high appreciation of Dr. Douglas' kindness in discussing Dr. Stansfield's paper and my own.

Dr. Douglas.—I hope you don't think that in the reference I made to costs that I was at all personal.

Dr. Porter.—I am sure you were not.

Dr. Douglas.—Because I have never known of an actual discourtesy by your students who have gone through the works. When you are visiting mines, without going into it minutely the general cost can be estimated; the scale of wages is a matter of publicity. Everybody knows what that scale is; what the miner gets and what the furnace man gets; and the cost of fuel is pretty well known, and as to the railroad rates they are supposed to be published. With two and two together you can generally arrive at the costs on some hypothetical ground, which after all is all you want for your students.

FIG. 1.—Macdonald Chemistry and Mining Building, McGill University.

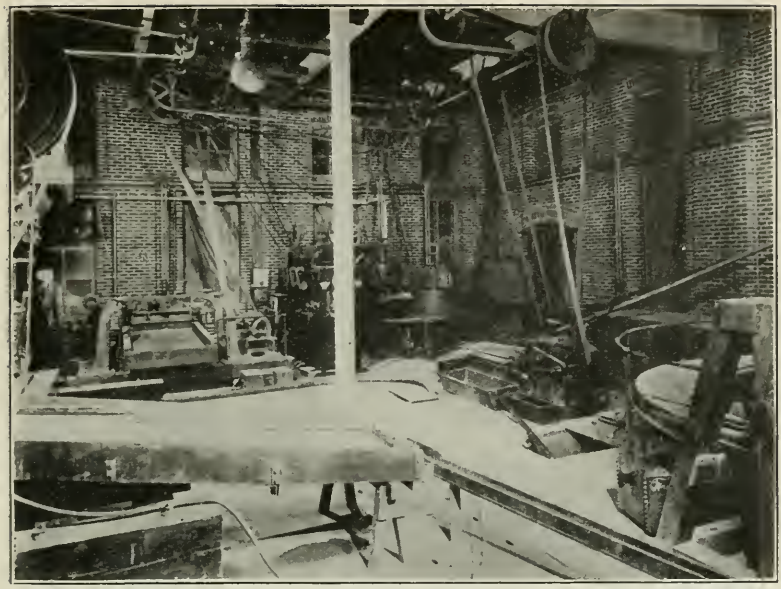


FIG. 2a.—Plates, Tables, Amalgam Pans, etc. Nos. 37a, 31, 49, 41, 43, 48.

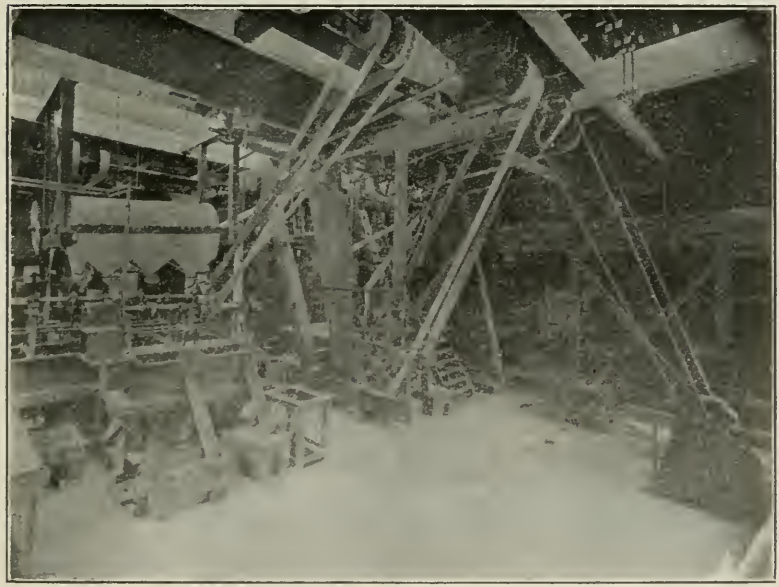


FIG. 2b.—Sampling Floor, Crushers, Rolls, Elevators, and Jigs, Nos. 1, 2, 3, 12, 20.

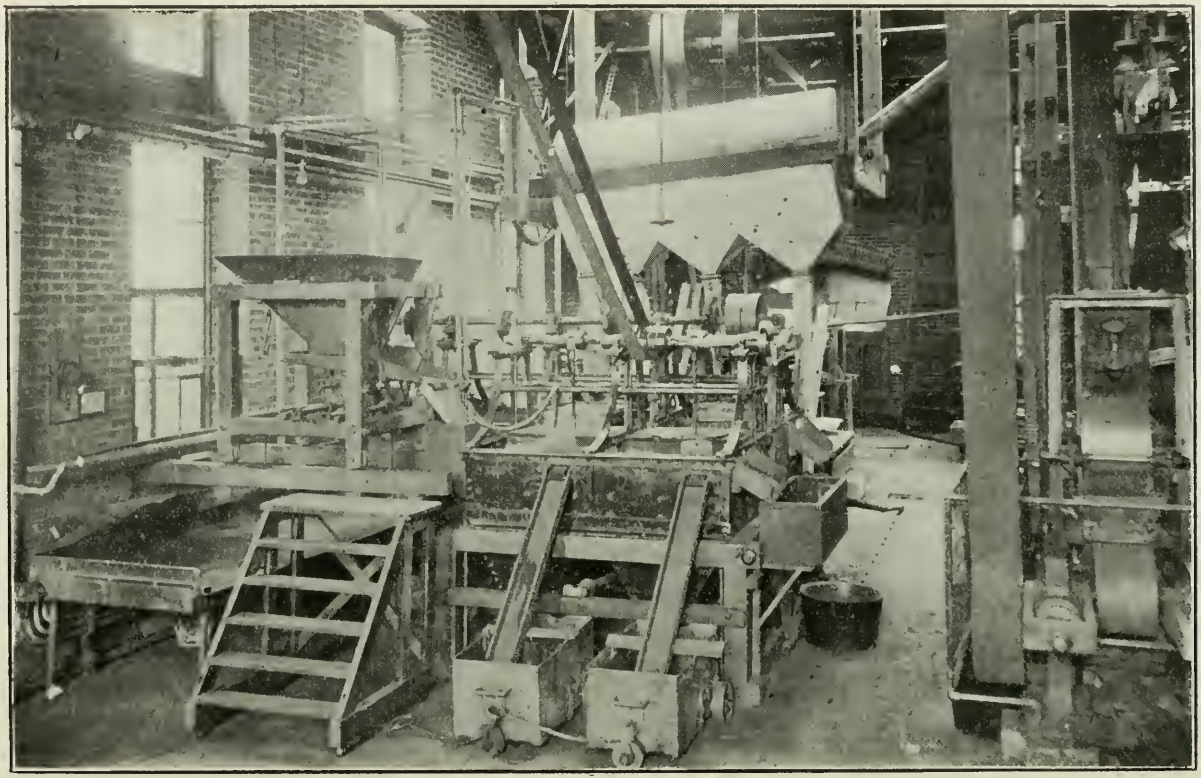


FIG. 3.—Jigs and Feeder, Trommel and Drying Table, Nos. 20, 15, 19, 47.

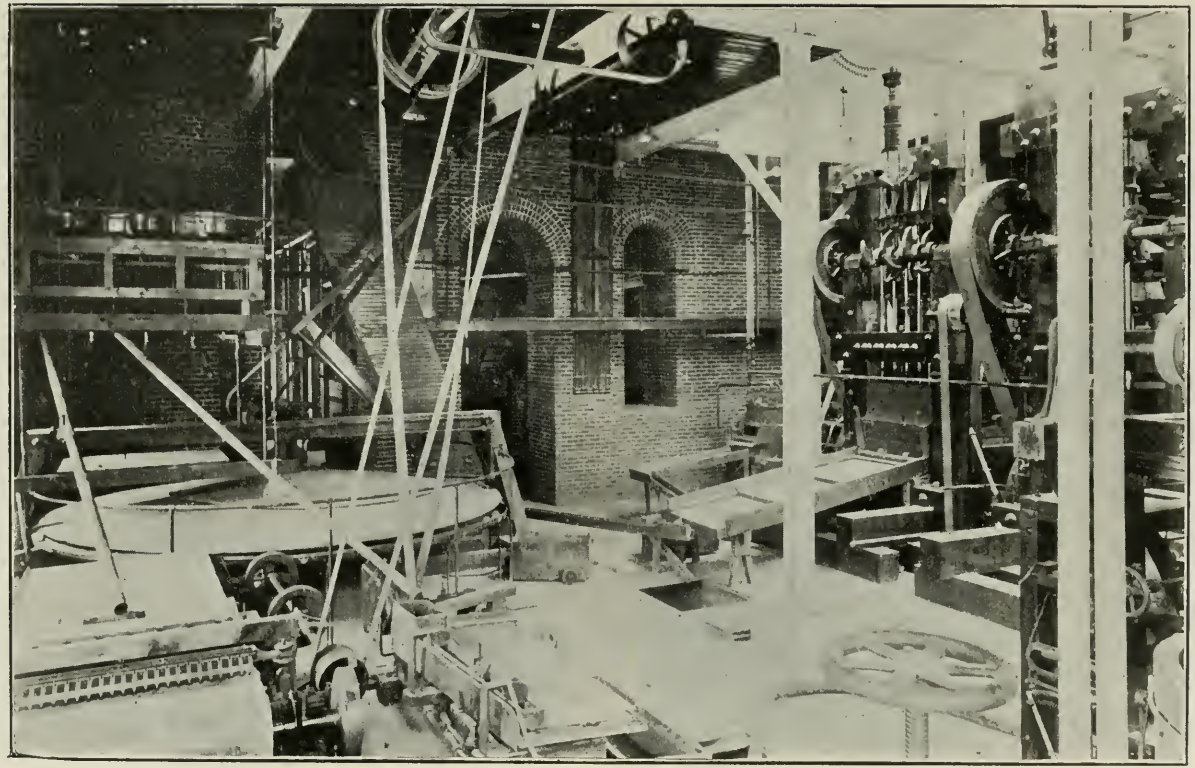


FIG. 4.—Batteries, Classifiers, and Tables, Nos. 8, 11, 37a, 25, 31, 36, 37.

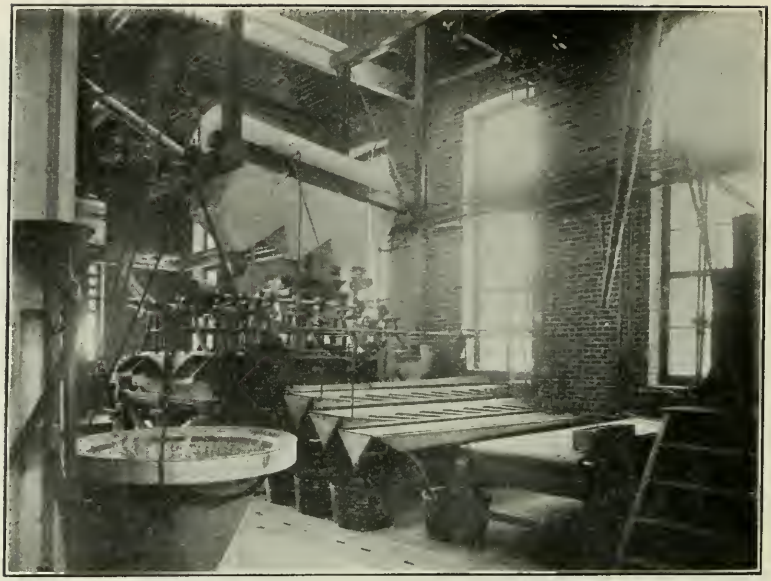


FIG. 5a.—Bartlett Table and Slimer, Jigs and Classifiers, Nos. 32, 33, 21, 22, 26.

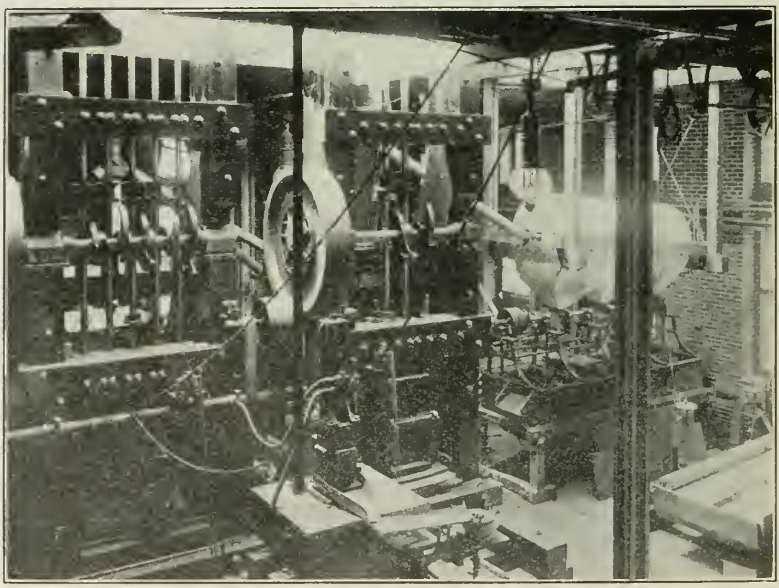


FIG. 5b.—Stamp Batteries, Steam Stamp, Jigs and Rittinger Table, Nos. 8, 9, 10, 21.

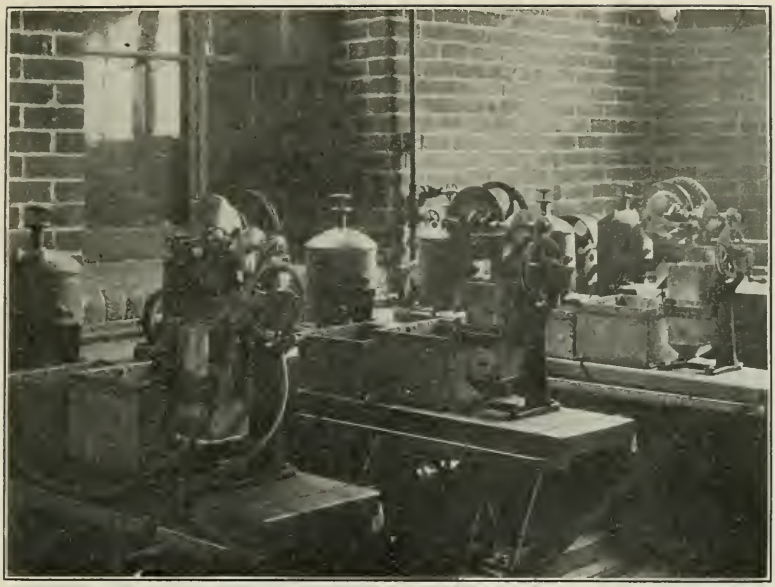


FIG. 6a.—Small Amalgam Pans and Vezin Jigs, Nos. 42, 23.

FIG. 6b.—Amalgam Pan and Settler and Drying Table. Nos. 40, 41 and 48.

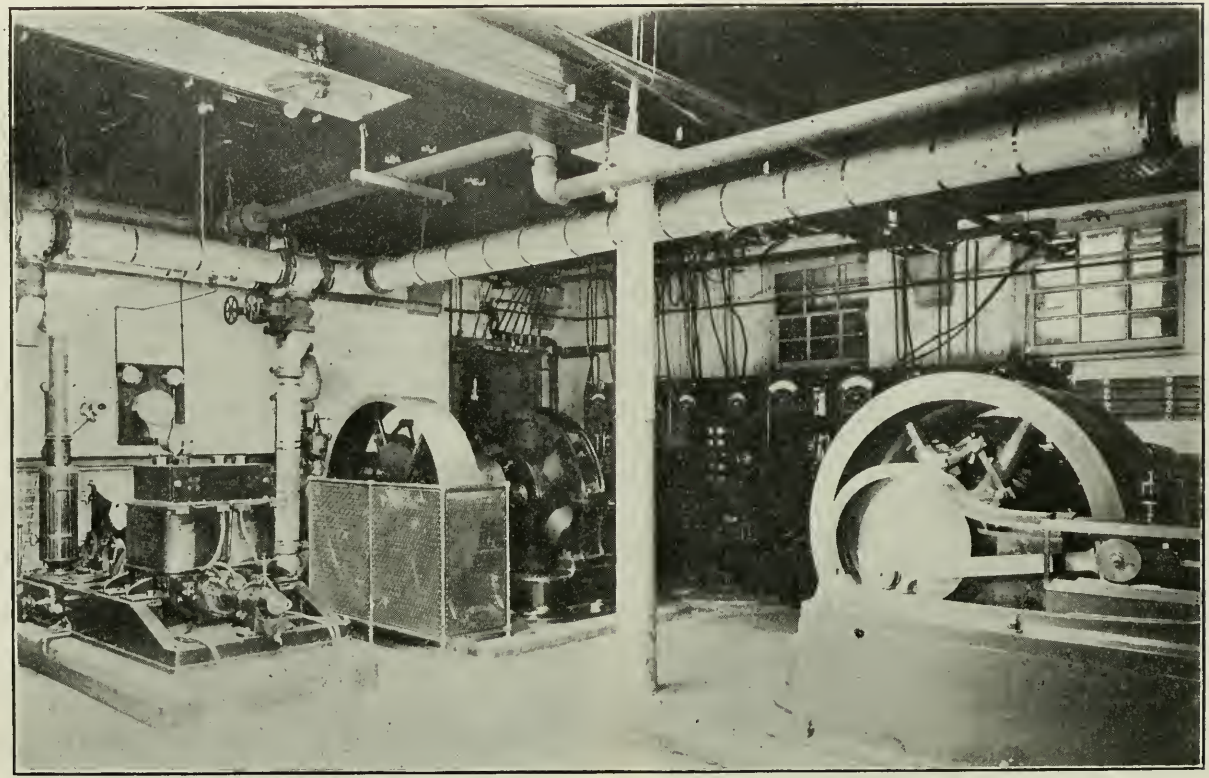


FIG. 7.—Electric Light and Power Station, Engineering Department.

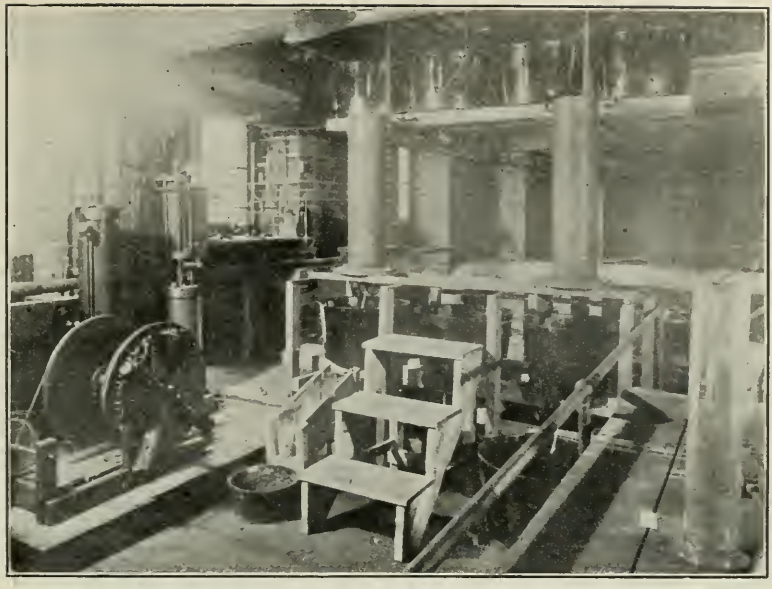


FIG. 8a.—Cyanide Plant, No. 49.

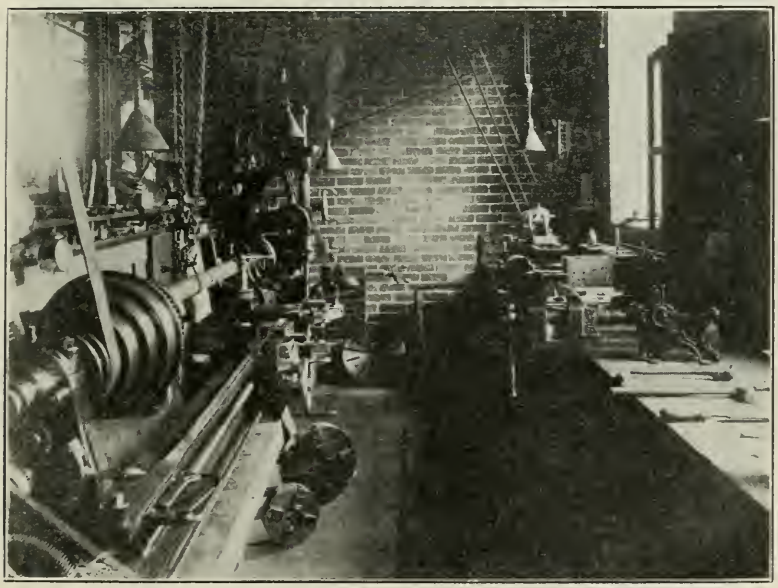


FIG. 8b.—Machine Shop, Mining Department.

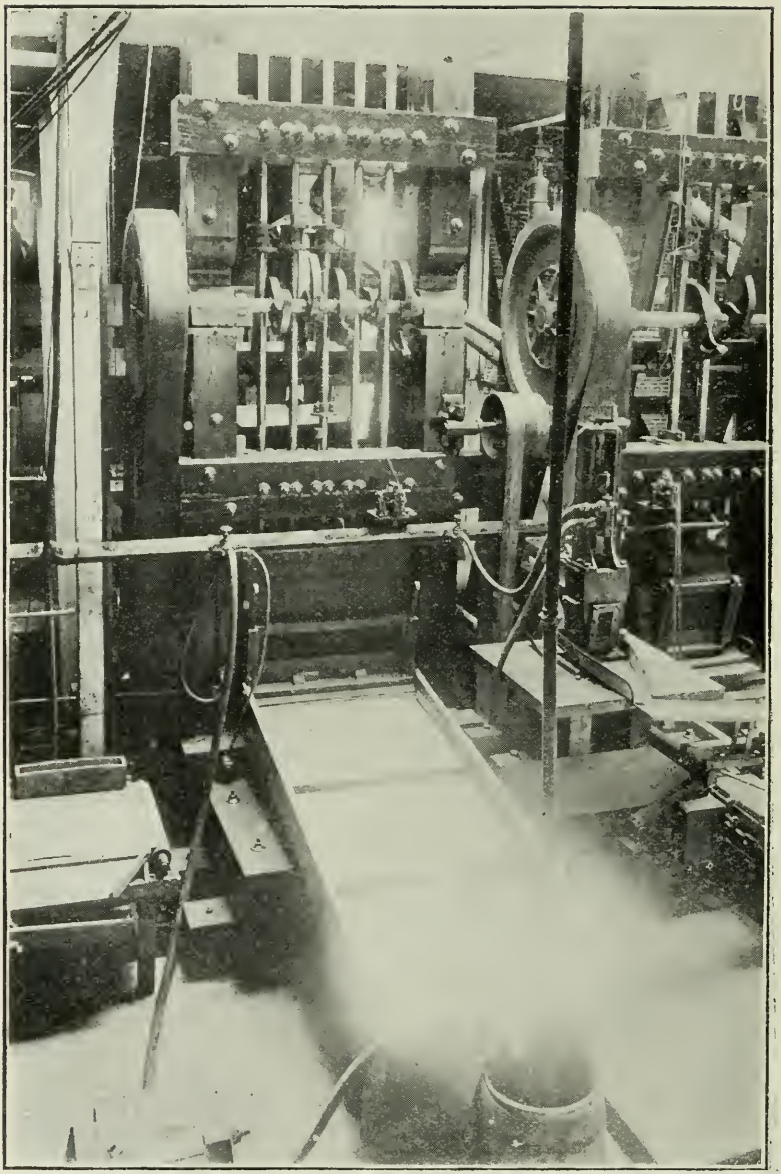


FIG. 9.—Stamp Batteries and Plates, Nos. 8, 9, 10, 37a.

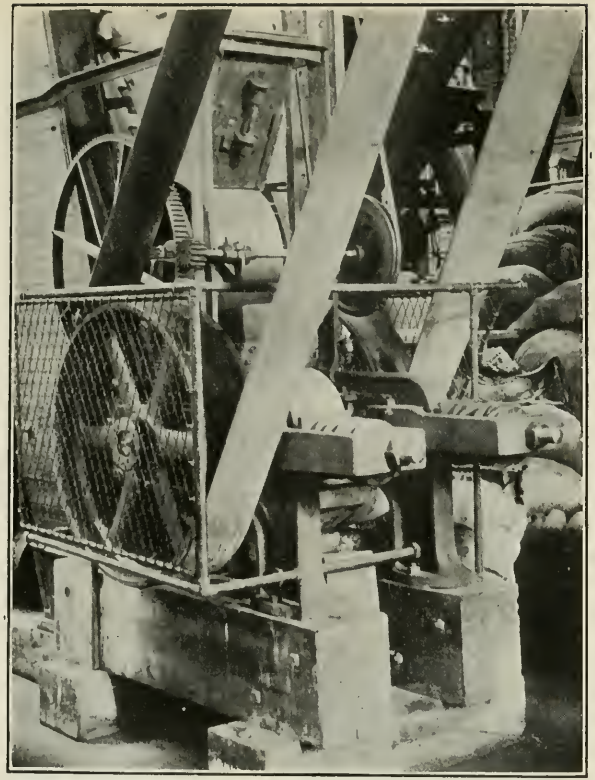


FIG. 10a.—Crushing Rolls, No. 12.

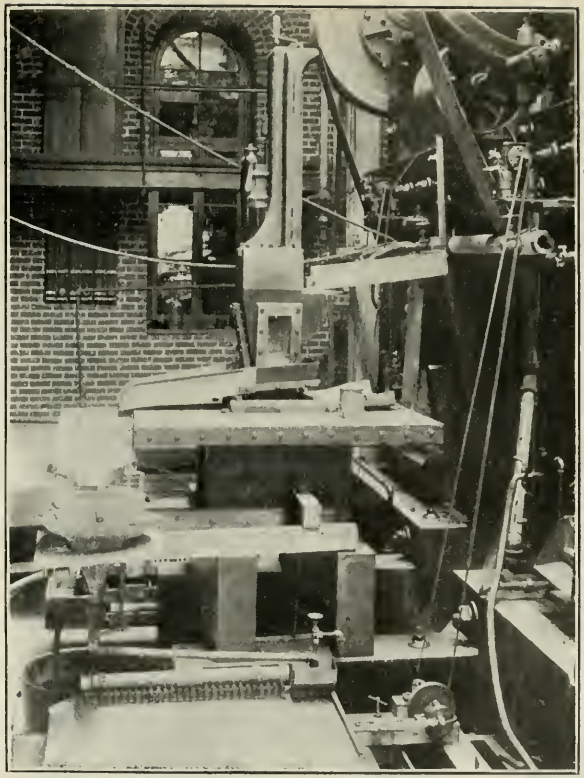


FIG. 10b.—Steam Stamp and Table, Nos. 10, 39, 27, 35.

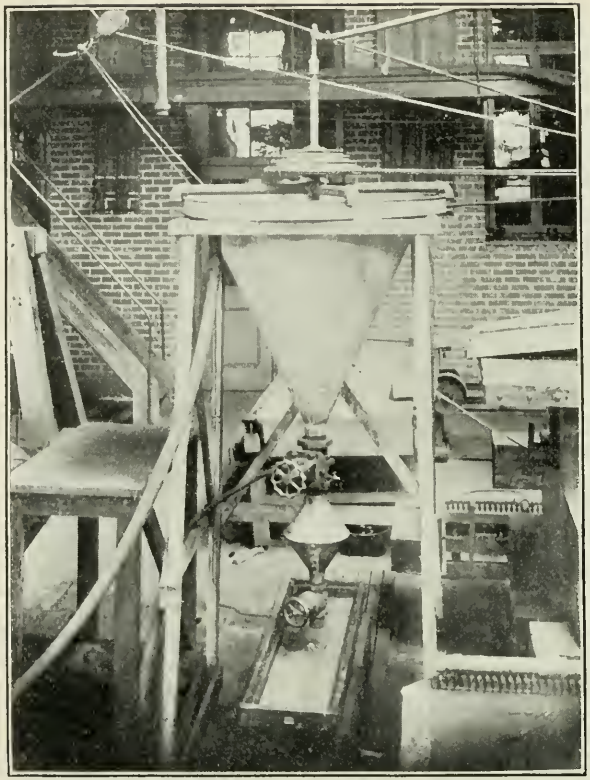


FIG. 11a.—Classifier arranged as Washer for Fine Coal, No. 26.

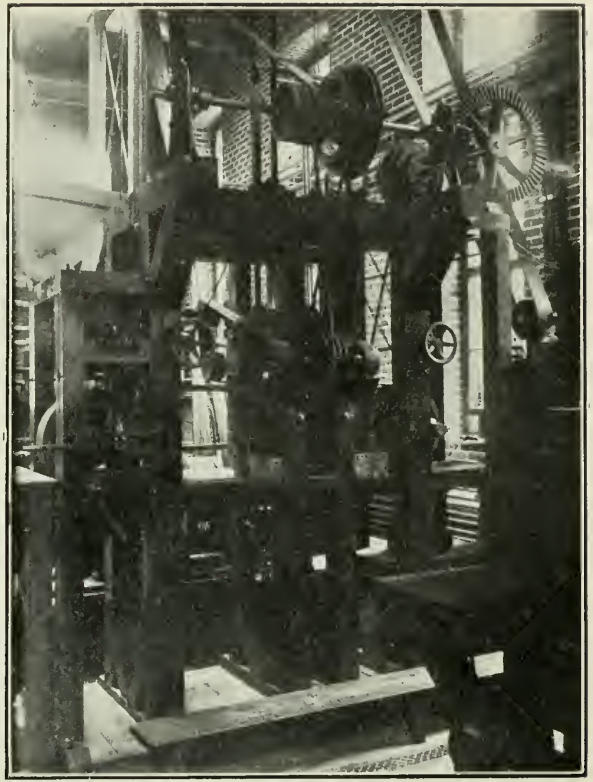


FIG. 11b.—Wetherill Magnetic Separator, No. 43.

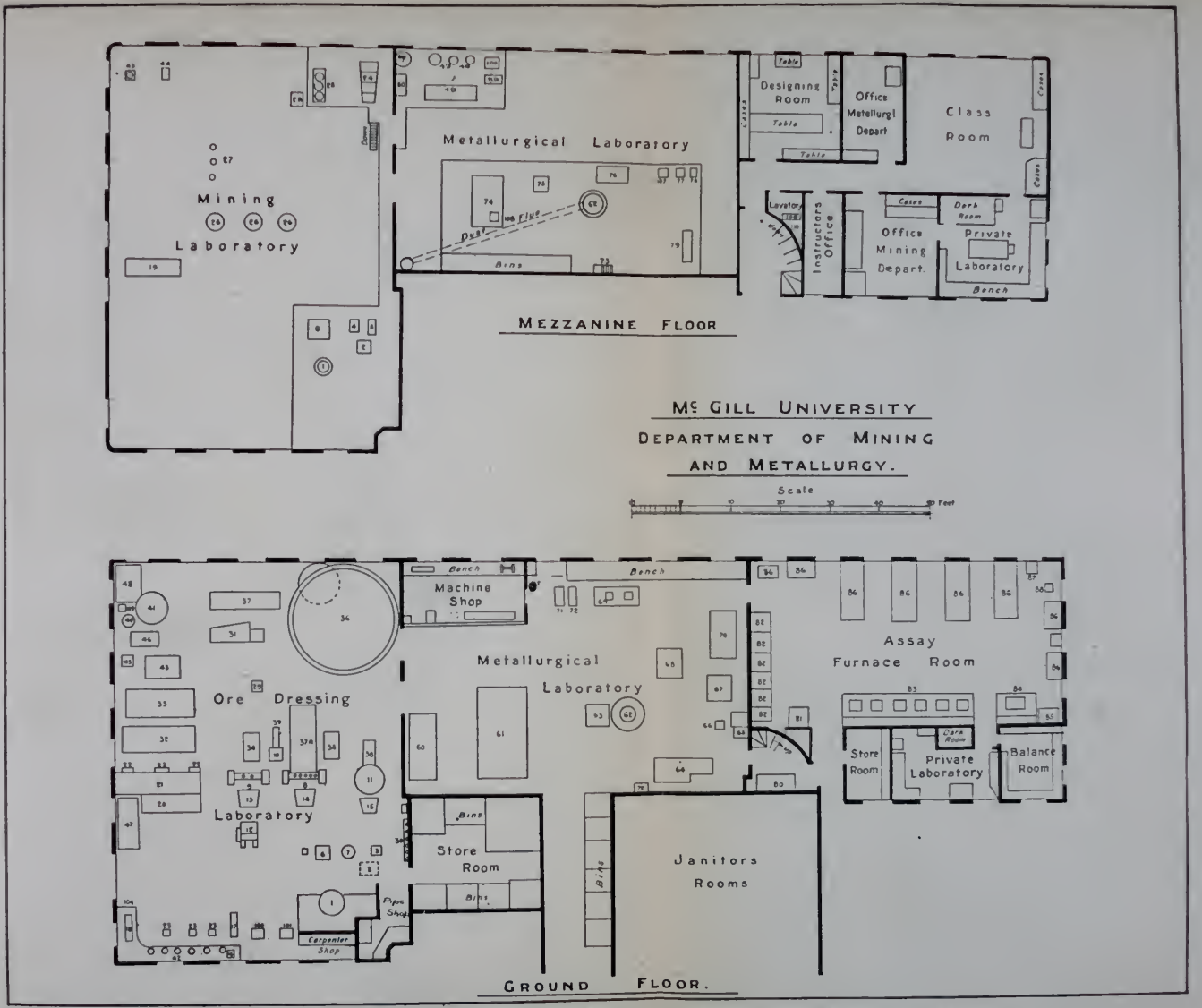


FIG. 12.—Floor Plans of Department of Mining and Metallurgy, McGill University.

KEY TO FLOOR PLAN OF McGILL MINING LABORATORIES.

Ore Dressing Dept.

1. Comet Crusher.
2. Dodge Crusher.
3. Ball Mill.
4. Sample Grinder.
5. Roller Jaw Crusher.
6. Hydraulic Lift.
7. Bridgman Sampler.
8. Five Stamp Battery, 600 lbs.
9. Two Stamp Battery, 1,000 lbs.
10. Steam Stamp.
11. Huntington Mill.
12. Crushing Rolls.
13. Suspended Challenge Feeder.
14. Challenge Feeder, Portable.
15. Tulloch Feeder, Portable.
16. Blake Crusher.
17. Shaking Screens.
18. Shaking Screens.
19. Trommel, with 3 fields.
20. Large Jig, 2 comp.
21. Large Jig, 4 comp.
22. Three small Jigs, 2 comp.
23. Three Vezin Jigs, 1 comp.
24. Spitzkasten, 4 comp.
25. Brown Sizer, 3 comp.
26. Three Large Cone Classifiers.
27. Three Small Cone Classifiers.
28. Pointed Box Settler.
29. Three Brass Tube Classifiers.
30. Seven Glass Tube Classifiers.
31. Wilfley Table.
32. Bartlett Table.
33. Bartlett Slime Table.
34. Small Riffled Table.
35. Small Riffled Table.
36. Evans Buddle.
37. Frue Vanner.

37a Battery Plates, Large.

38. Battery Plates, medium.
39. Battery Plates, small.
40. Amalgamation Pan, large.
41. Settler.
42. Six Amalgamation Pans, small.
43. Wetherill Magnetic Separator.
44. Heberli Magnetic Separator.
45. Centrifugal Separator.
46. Pneumatic Jig.
47. Steam Jacketed Drying Table.
48. Steam Jacketed Drying Table.
49. Cyanide Plant.
50. Elmore Plant.

Metallurgical Dept.

60. Brueckner Roaster.
61. Hand Roaster.
62. Blast Furnace, water jacketed.
63. Fore-Hearth.
64. Cupellation Furnace.
65. Wind Furnace.
66. Forge.
67. Gas Muffle.
68. Gas Furnace Table.
69. Electric Furnace Table.
70. Chlorination Barrel.
71. Power Saw.
72. Grindstone.
73. Drop Test.
74. Electrolytic Table.
75. Power Lift.
76. Iron Table.
77. Polishing Apparatus.
78. Small Blower.
79. Experimental Open Hearth Furnace.
80. Recording Pyrometer.
81. Soft Coal Muffle.
82. Six Wind Furnaces.
83. Six Muffle Furnaces.
84. Three Gas Muffle Furnaces.
85. Draft Cupboard.
86. Seven Working Benches.
87. Bucking Board.
88. Bullion Rolls.
89. Root Blower.
90. Hydraulic Press.

Power, Etc.

100. 15-H.P. Motor.
101. 15-H.P. Motor.
102. 15-H.P. Motor.
103. 10-H.P. Motor.
104. 2-H.P. Motor.
105. 2-H.P. Motor.
106. 2-H.P. Motor.
107. 2-H.P. Motor.
108. 1-H.P. Motor
109. 2-H.P. Motor.
110. Ventilation Fan.

THE TEACHING OF METALLURGY IN COLLEGE LABORATORIES, WITH A DESCRIPTION OF THE METALLURGICAL LABORATORIES OF McGILL UNIVERSITY.

By A. Stansfield, D.Sc., A.R.S.M.

Professor of Metallurgy, McGill University, Montreal.

In writing an account of the Metallurgical Laboratories of McGill University, it became evident that a broader subject, the teaching of Metallurgy in college laboratories, its uses and its limitations, should first be considered. A discussion of the subject accordingly forms the introduction to this paper.

Metallurgical laboratory teaching has not yet reached any standard pattern. The widest divergence of opinions exists with regard not only to the scope of such teaching but even as to whether any metallurgy worthy of the name can be taught at all in the college laboratory.

A recent paper by H. C. Jenkins,* on "The Equipment of Laboratories for Advanced Teaching and Research in the Mineral Industries," produced such a crop of discussion in the Institution of Mining and Metallurgy, in London, that it would be hard to find anything to add to what was said or written on that occasion.

Without raising the wider question, whether metallurgical laboratory teaching is worth doing at all, it will be advisable to indicate the uses of such laboratories in metallurgical teaching.

Students on this continent have very great facilities for obtaining practical experience in smelters and metallurgical works both during the annual summer schools that are held in connection with most of our mining schools, and by taking subordinate positions in such works during the long summer vacation. It is therefore unnecessary to attempt in the laboratory to instruct the student in the practical operations of roasting or smelting which he can learn so much more easily and perfectly

* Trans. Inst. Mining and Metallurgy, London, Vol. XIII.

in the smelter. There are however many parts of a metallurgist's education that can be more easily gained in the laboratory than at the smelter.

The metallurgical laboratories of a university have several distinct uses, all of which, however, should conduce to the education of the student, and these uses may be outlined as follows:—

1. *The use of furnaces and other appliances to illustrate the lectures.*—This is particularly useful in lecturing to junior students who have not yet visited metallurgical works.

For such students the laboratory furnaces, if on a reasonably large scale, tend to give concrete ideas of the real furnaces, and also enable some metallurgical principles, for example the principles involved in firing with hard or soft coal, coke, gas or oil to be presented vividly.

2. *The teaching of fire assaying.*—This, although forming a part of the teaching in metallurgical laboratories, will not be considered in this paper.

3. *The use of metallurgical measuring instruments.*—The pyrometer for measuring high temperatures, the calorimeter for measuring the calorific power of fuels, and the microscope for the examination of steel and other metals are all instruments whose use should be acquired by the metallurgical student.

4. *Properties of metals, fuels, and refractory materials.*—The more important mechanical, physical and chemical properties of the common metals, alloys, fuels, refractory materials and fluxes can be easily learnt with the aid of simple furnaces and appliances in the laboratory, and knowledge so gained is far more useful than if acquired from books.

5. *Study of metallurgical reactions.*—The reactions that are at the root of many metallurgical operations can be studied very perfectly in the laboratory, with the aid of simple and inexpensive appliances. Thus the roasting of an ore can be exactly studied, and the chemical changes that take place, and the temperature necessary for each stage of the process can be determined. Prof. Howe† shows how such work can be carried out by a class of

† H. M. Howe, "Metallurgical Laboratory Notes." In the introduction to this work he discusses the teaching of metallurgy, and insists that principles rather than practice should be taught in the College laboratory.

students, but in many cases the object of such experiments would be to improve commercial practice in certain particulars, and should be taken as an advanced student's thesis or even as research work by a member of the teaching staff.

6. *Large furnace runs.*—In laboratories provided with large scale furnaces for roasting or smelting, it is usual to have occasional runs of such furnaces. The lecturer explains beforehand the particular problem that is to be met and the calculations necessary for making up a smelting charge. The students carry out as far as possible the operations during the run, and after the clean up, the result of the run is presented to the class and compared with the results predicted and with the results that would be obtained in actual practice.

When time permits, it is desirable that the students should themselves make the chemical analyses before and after the run, and the sampling of the materials composing the charge and of the products of the run affords valuable experience. The opportunity may also be taken to sample and analyse the furnace gases, determine the furnace temperatures, measure the amount of air entering the furnace, and the amount and rise of temperature of the jacket water in the case of a blast furnace campaign.

Taken in this way a small furnace run has an educational value quite apart from the practical experience gained by the student, and is not open to the criticism of being merely a bad imitation of works practice.

7. *Students' theses.*—One of the most important uses of metallurgical or ore dressing laboratories is for enabling advanced students to attempt to solve some definite problem in connection, for example, with the treatment of an ore. A large number of such problems can be worked out satisfactorily on quite a small scale, and then if time permits can be repeated on as large a scale as the laboratory affords, thus enabling the effect of scale to be quantitatively determined.

Work of this character tends to throw the students largely on their own resources, and affords extremely valuable training, teaching precise experimental methods, careful observation and correct reasoning from the results of experiments; it also encourages initiative in devising new methods.

8. *Use of laboratories by teaching staff.*—Apart from direct use by the students, the laboratories are useful to the staff; their use tends to prevent the teaching becoming too academic in character. Each member of the staff should have some research, either on theoretical or practical lines. Outside testing or experimental work should be undertaken to keep the staff in touch with technical and commercial requirements. Any information directly gained in this way is far more valuable than that obtained at second hand or from books.

Having outlined some of the uses of a metallurgical laboratory one can the better consider the actual equipment and how far it comes up to the requirements already outlined.

The laboratories at McGill (Fig.8) consist of a furnace room 60 ft. by 38 ft. and 20 ft. high, a room for fire assaying 54 ft. by 24 ft. and smaller rooms for balances, chemical and photographic work, microscopy and pyrometry.

GENERAL SUMMARY OF EQUIPMENT.

The main laboratory contains a water jacket blast furnace with interchangeable crucibles for smelting either lead or copper ores, a hand reverberatory roasting furnace, a Brueckner roaster, a cupellation furnace, and a chlorination barrel.

These appliances are on a relatively large scale, and will be described later in detail.

There is also a large, 17 inch, crucible furnace provided with forced draft, a large gas muffle furnace or forge, a brick topped table with gas and air connections for experimental gas furnace work, another brick topped table equipped for electric furnace work. A table with terminals for low voltage current for electrolytic experiments and a model open hearth regenerative gas furnace.

The fire assaying room contains a number of wind furnaces and muffle furnaces for coke, soft coal, oil and gas which will not be considered in the present paper.

The several furnaces may now be considered in detail with the uses to which they can be put.

Brueckner roasting furnace.—The rotating drum has an external diameter of 2 ft. 8 inches, and a length of 5 feet, and is

lined with 4½ inches of fire brick. It is fired by means of soft coal or wood in a movable firebox. The charge of ore used is about 250 lbs.

Hand reverberatory roasting furnace.—A view of this is given in Fig. 7b. The hearth measures 6 ft. by 14 ft. internally, and will take about 1,500 lbs. of ore.

There are three working doors on each side of the furnace. The flue descends at the end of the furnace and returns beneath the hearth constituting a dust chamber.

The fire box was originally 4 ft. by 2 ft., but the consumption of coal has been greatly reduced and the efficiency of the furnace increased by reducing the fire box to 3 ft. by 1½ ft. and introducing a steam jet forced blast into the closed ash pit, thus turning the fire box into a gas producer.

The chemical and physical changes that take place during the roasting of powdered ore can be studied quite as well if not better in a small gas fired muffle furnace, but the reverberatory furnace affords approximate information with regard to the roasting of any particular ore on the large scale, and has much educational value in regard to the economical firing of such furnaces. One of the difficulties connected with the use of large reverberatory furnaces in the laboratory is the great length of time that must elapse before the furnace has become thoroughly heated.

A large roasting furnace is sometimes necessary in order to roast quantities of ore for subsequent smelting operations.

The stall or kiln roasting of lump ores of copper has been successfully carried out on a small scale in one of the wind furnaces.

Water jacket blast furnace.—This is circular, having an internal diameter of 21 inches at the tuyeres, and 33 inches at the top of the jacket. The height from tuyeres to charging door is 7 ft.

There are 3 tuyeres of 2½ inches diameter, and the furnace is blown by a No. ½ Root's blower driven by a 15-H.P. electric motor.

There are two crucibles both on wheels, the one for lead smelting containing a large well with the usual siphon tap for the lead, and spout for the slag. The crucible for smelting copper ores is much shallower, and originally the matte and slag were tapped

periodically into slag pots where the matte settled by gravity and was separated from the slag when cold. The slag obtained in this way was never very clean, and attempts to obtain a better separation were made, first with an internal crucible, tapping the slag and matte off at different levels ; and finally by adding a fore-hearth in which the matte settled from the slag. The fore-hearth is 34 inches by 25 inches by 19 inches high externally, and is lined with ½ inch asbestos, 2½ inches of fire brick and 2 inches of brasque and covered with 3 inch fire clay tiles, as it was feared that a fore-hearth with so small a flow of slag and matte would be apt to freeze up. To further prevent loss of heat, the usual spout between furnace and fore-hearth is omitted, and the molten charge allowed to enter the fore-hearth through a covered channel below the level of the slag in the fore-hearth. It is in fact the Herreshoff fore-hearth, but without any water cooling.

As a further precaution a gas blowpipe is arranged so that a flame can be introduced between the surface of the slag, and the tile cover if any signs of freezing are observed.

A granulating apparatus is arranged to deal with the slag and works satisfactorily. The general arrangement is shown in Figs. 4 and 5. The slag from the fore-hearth is very much cleaner than had previously been obtained.

The blast furnace can easily be blown in, run for two or three hours and blown out during the student's working day, the crucible and fore-hearth having been heated up previously; but the work of cleaning up and preparing for the next run is very considerable.

During the run, in addition to weighing and charging the ore, fluxes and coke and to manipulating the molten slag and matte, the students are required to determine the volume and temperature of the jacket water, the speed of the blower, pressure of blast, condition of furnace at the tuyeres and on top of the charge, rate of flow of slag and of granulating water, etc., and the data so obtained are worked up and form the subject matter of a subsequent lecture after the necessary analyses have been made.

Having obtained satisfactory slag settling facilities, the next problem to be attacked was that of pyritic smelting, and the first experiment made in that direction met with a reasonable

degree of success; the slag and matte analyses agreed very closely with the predicted values and interesting information was obtained from the gas analyses.

The author considers that these furnace runs very greatly increase the value of the lectures on this branch of the subject.

In running a blast furnace, even so small as the one at McGill, it is noticeable that the students are apt to be occupied by the actual operations of weighing, charging, tapping, etc., to such an extent that they are likely to lose the educational value of many of the phenomena to be observed. As it is not intended to train the students as expert weighers, chargers or tappers this preoccupation with the actual operation is apt to detract from the educational value of the run, and as far as the investigation of the principles of smelting goes, a furnace on even smaller lines would answer every purpose, and would have the additional advantages that less ore and fuel would be needed, that the students could be left more entirely to their own devices in running the furnace, and that they would be able unaided to clean up the products of the run and make out balance sheets.

The author has on two occasions built and operated with students small brick furnaces 9 inches square inside, and has smelted in each a few hundred pounds of copper ores without serious difficulty. As so small a furnace would inevitably freeze up if it were attempted to tap the products, a small fore-hearth was added and the molten products were kept hot by a flame issuing from the crucible of the furnace.

Working on a small scale, it is usually impossible in furnace work to imitate both the arrangement and the results of large scale operations. One may build and operate a model furnace, but it will not usually give normal results. To obtain good conditions, it is usually necessary to depart widely from the adopted type of furnace—such changes being due mainly to the very much greater loss of heat that occurs on the small scale.

In metallurgical laboratory teaching, when this alternative offers, the author would not recommend in general that the works pattern should be followed, but that an entirely new furnace should be designed that will enable the principles to be experimented with and demonstrated, and to have perhaps a few large scale appliances that can be at once models and working furnaces.

English Cupellation furnaces.—This furnace was originally installed as the smallest furnace that could be obtained ready made that would serve as a reverberatory smelting furnace. It is obvious that a metallurgical laboratory would not often have enough argentiferous lead to need the use of a 48 inch by 30 inch test. The furnace has been used for smelting lead ores and it is intended to remodel it with a view to the regular smelting of either lead or copper ores. In this, as in the roaster furnace, a steam jet forced draft has been added with great advantage.

Crucible furnace.—A crucible furnace 17 inches square has been provided with forced blast, and it is easy in this furnace to melt steel in crucibles or to test the fusibility of refractory materials.

The blast for the blast furnace and for the crucible furnace is furnished by a No. ½ Root's blower driven by 15 H.P. motor.

Gas furnaces.—For metallurgical teaching and research purposes, the ordinary city gas affords an ideal heating agent for many purposes, and as Prof. Howe very clearly points out, it is better in general to use a fuel that will afford constant, easily regulated and definite conditions of temperature and of atmosphere in which to study definite metallurgical problems, than to introduce at the same time the difficulties connected with the use of coal or other solid fuel.

A 1 H.P. high pressure blower has recently been installed and piped to different parts of the laboratory and with the aid of some home made blow pipes of various sizes and a few fire bricks it is easy to construct small gas furnaces as occasion arises.

A brick topped table (Figure 3) provided with a hood and connections for gas and air is specially convenient for this class of work, while a combined forge and muffle furnace obtained from the American Gas Furnace Company has proved very convenient for roasting small quantities of ore, for fire assaying and for researches in which a number of bars of steel were heated nearly to their melting temperature in order to ascertain the conditions under which steel became "burnt" and the true nature of the so-called burning.

Those who have designed small scale furnaces may be interested to hear of an experimental open hearth furnace constructed at

McGill. (Fig. 7a.) It was built as a model on the 1 inch to the foot scale of a 50 ton tilting open hearth furnace, with the exception that coal gas was used and that chequers were provided only for the air. Without going into detail, it may be said that using an amount of gas proportionately about equal in heat value to that used in the large furnace, the chequers did not have nearly the effect that was expected, and it was found that on account of the relatively larger area of the walls of the small scale furnace, and the actually smaller thickness of the walls the loss of heat was so great that the chequers never became thoroughly heated.

Using a larger supply of gas the supply of preheated air was inadequate to burn it, and it became obvious that for small scale gas furnaces the gas blow pipe with air preferably preheated in a pipe stove was decidedly more efficient, and that in order to exhibit the effect of chequers in preheating air the furnace would have to be built larger, using producer gas, or else the most extreme care should be taken to avoid loss of heat by the use of thick walls containing very poorly conducting layers, such as asbestos pulp.

It is intended to construct a small gas producer with a view to illustrate details in the production and uses of gaseous fuel.

Electric furnaces.—A brick topped table (Fig. 2) has recently been constructed to which not only the electric current but also gas, air and water have been led. The gas and air being intended as a substitute for the more costly electric power for the drying and preliminary heating of certain of the electric furnaces; while water is sometimes needed for cooling the terminals and metal casings of furnaces.

Many varieties of electric furnace have been experimented with, but owing to the relatively high voltage and low current available, the arc furnaces have been more generally useful. The horizontal arc furnace of Moissan has been found especially useful in melting metals for demonstrational purposes. The vertical arc furnace is also useful for melting metals and for reducing metals from their ores. The production of calcium carbide in this form of furnace has been found to be a suitable reise for class purposes.

For the electrical smelting of ores, furnaces of the Héroult type have been used in which two vertical carbons dip into the furnace and arcs are formed between these and the charge. Resistance furnaces are more satisfactory for many purposes than arc furnaces, but the necessity of using current at 110 volts renders small resistance furnaces exceedingly wasteful of power.

The power available for electric furnace work is about 200 amperes of direct current at 110 volts, and while this is sufficient to exhibit the principles of electric heating and to enable many experimental points to be determined, it is inadequate for carrying out electric smelting even on the smallest satisfactory scale, especially when low resistance furnaces have to be used. It is hoped that a sufficient supply of alternating current at 110 volts and a transformer for reducing to lower voltages will be provided to enable some of the newer processes to be worked out on a scale that would afford information to intending manufacturers, and training for students who wish to specialize in electro-metallurgy.

Microscopy.—The outfit consists of cutting and polishing machinery for preparing the specimens of steel or alloy, a special microscope for examining the specimens and a long photographic camera for recording the microscopic structures so revealed.

Pyrometry.—A thermo-electric pyrometer is usually employed for measuring temperatures in the laboratory. This is connected to a galvanometer which indicates the temperature, and a photographic apparatus enables continuous records of temperature to be obtained. Several pyrometers of the Callendar type are also available for use.

Calorimetry.—A Mahler bomb calorimeter is used for determining the calorific power of fuel.

Analytical work and fire assaying.—The students are expected to have attained to a reasonable degree of proficiency in these subjects before commencing their final year's work, and the laboratory work in that year is so arranged as to involve some quantitative chemistry and fire assaying, thus enabling the students to make use of the knowledge they have gained in these methods. The necessity for a reasonable degree of speed and reliability in their work is impressed upon them in this way, and they become more ready to carry out such work at short notice.

Electrolysis.—A table has been fitted up for electrolytic work, being provided with a 1 H.P. 10 volt dynamo driven by a 1 H.P. motor, a small storage battery has been added to enable experiments to be left running over night.

Within the limits of this paper it has been impossible to do more than hint at most of the experiments that have been made or can easily be carried out in these laboratories; the limiting consideration is usually the short time at the disposal of the student rather than any limitations of the laboratory. Nevertheless the author is only too painfully aware of deficiencies in the equipment, and continually endeavors as time and money will permit to raise the standard both of the laboratories and of the work that is done in them.

DISCUSSION.

Dr. PORTER.—Two papers were prepared on the question of Laboratory Teaching by Dr. Stansfield and myself. I have tried to cover the ground in a general way, and the details have been treated by Dr. Stansfield.

Dr. STANSFIELD.—The subject covered by my paper is somewhat similar to Dr. Porter's. It relates to the teaching of metallurgy in the laboratory, and contains a description of our laboratory at McGill. The main object of the paper is to obtain information from those of you who have had an extended experience in commercial work, as to whether the line of teaching which I shall outline is, in your opinion, the best for the young engineer. The subject of metallurgical laboratory teaching is a very thorny ore. It has been recently discussed in the Institute of Mining and Metallurgy in London, with a view to future equipment of the Royal School of Mines. I have given in this paper a short synopsis of the teaching at McGill and a few ideas with regard to the general principles as I conceive them, of metallurgical laboratory teaching. I wish to repeat that the object of the paper is to elicit discussion on this subject. At the end of the paper I refer to electrical furnaces. I have been trying to advance

electric furnace work as far as possible at McGill. We have not at present a sufficiently large electrical power to carry on the electric smelting of ores, but I am hoping that some munificent manufacturer may perhaps be able to afford us some assistance in this matter. I should like to have even a small equipment.

Dr. Porter.—Would Dr. Stansfield say what he considers a small electric furnace. What is the electrical horse-power?

Dr. Stansfield.—An equipment for about 50 kilowatts or 65 electrical horse-power would be satisfactory.

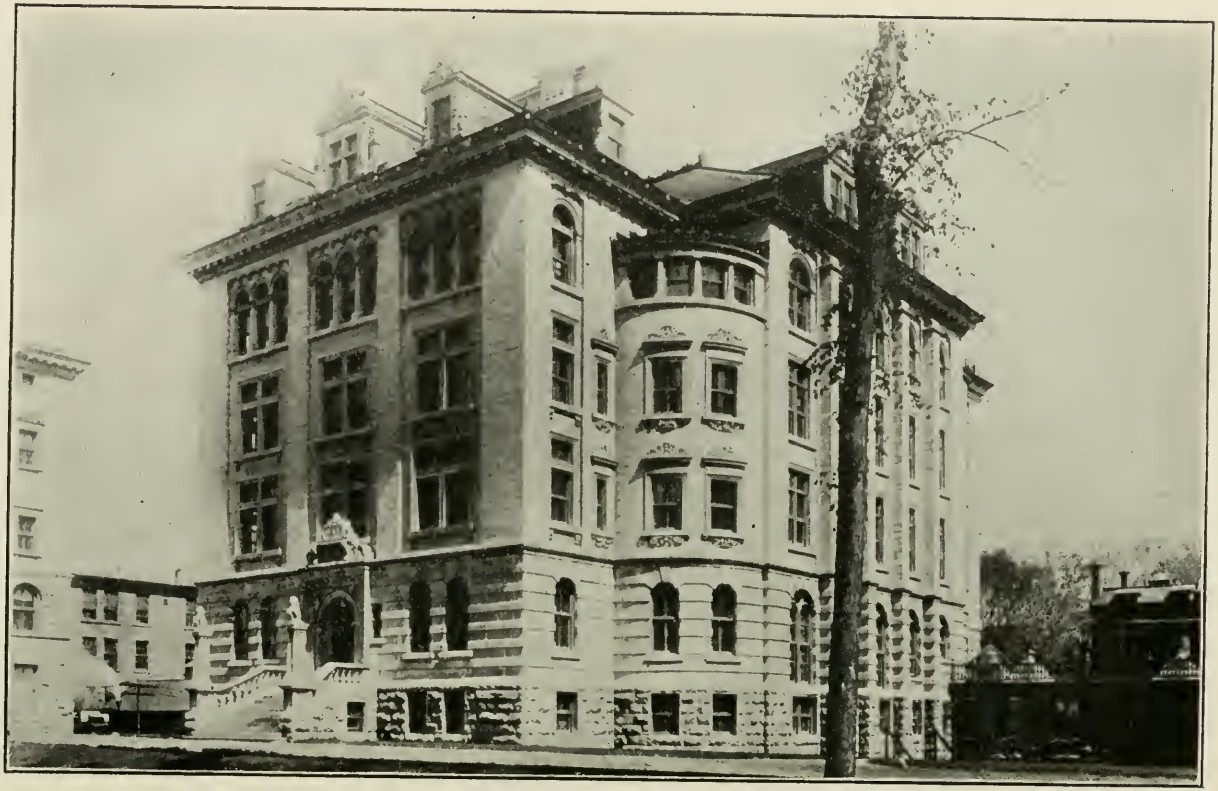


FIG. 1.—Macdonald Chemistry and Mining Building, McGill University.

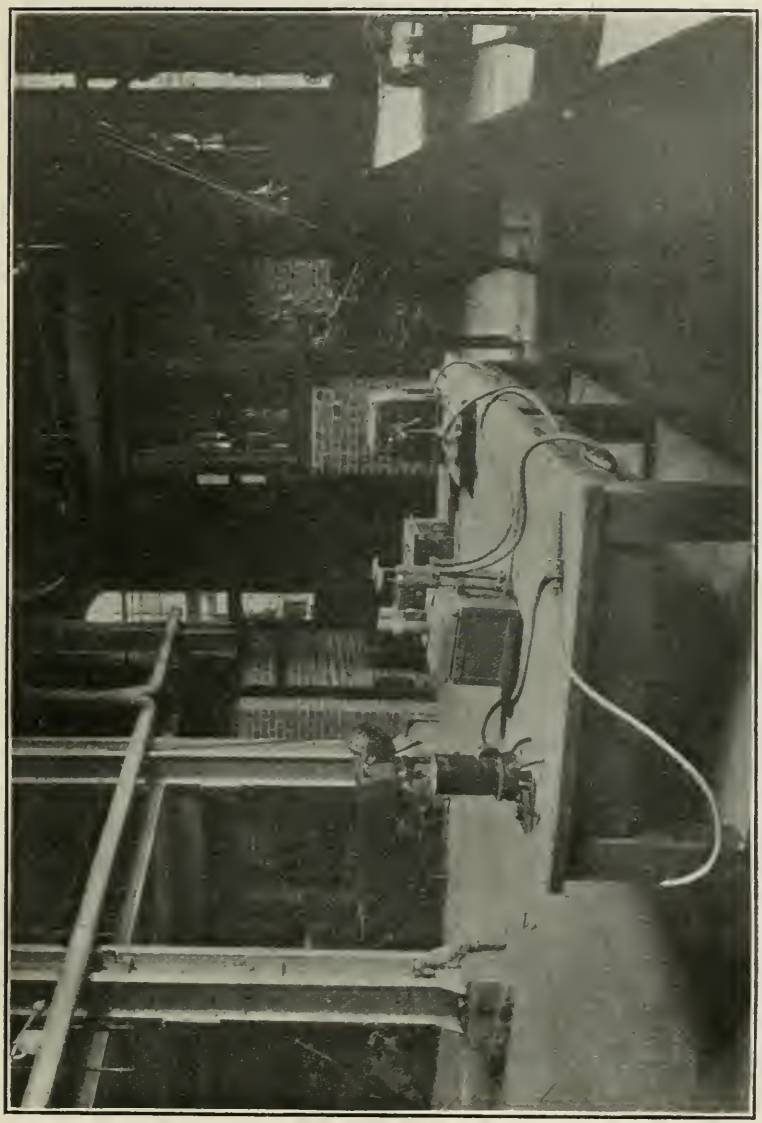


FIG. 2.—Electric Furnaces, No. 69.

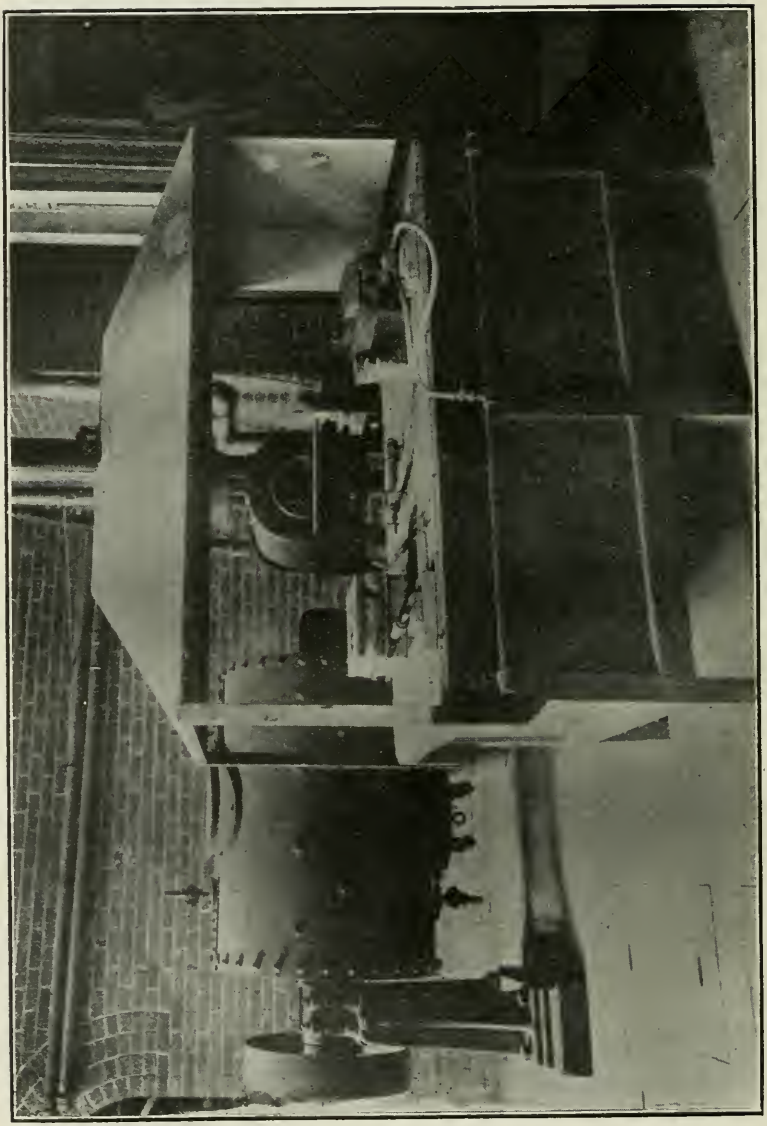


FIG. 3.—Gas Table, Gas Muffle and Chlorination Barrel, Nos. 67, 68 and 70.

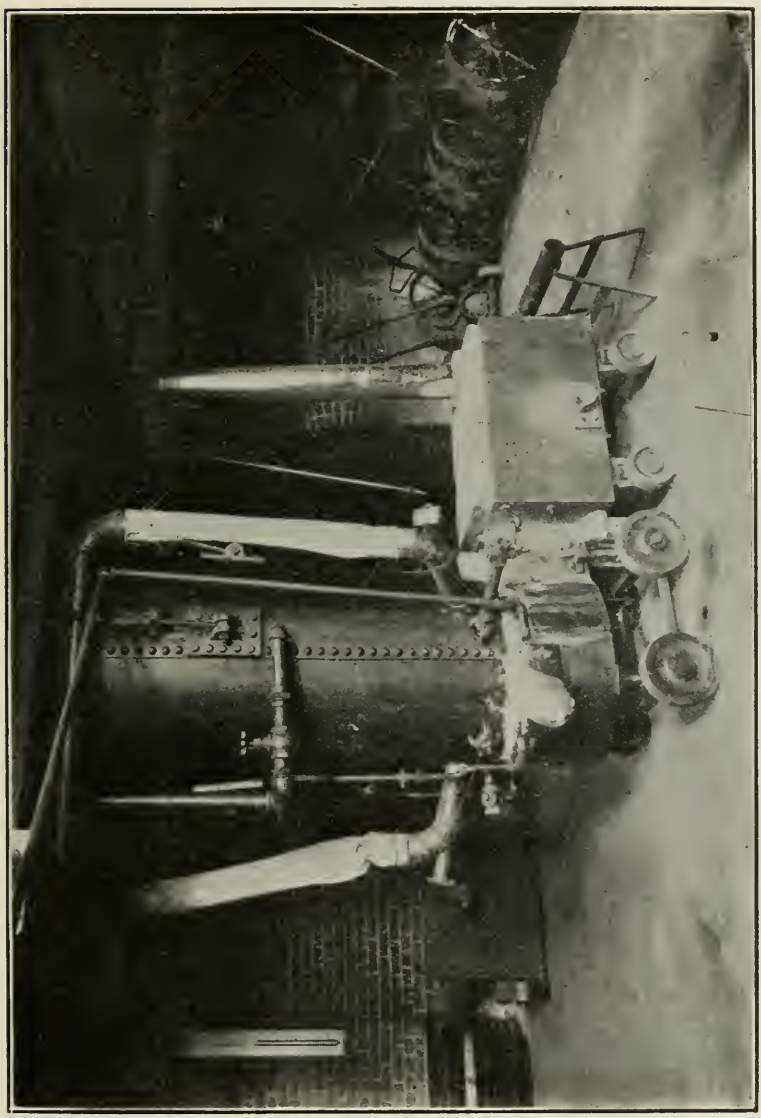


FIG. 4.—Water Jacket Blast Furnace and Fore Hearth, Nos. 62 and 63.

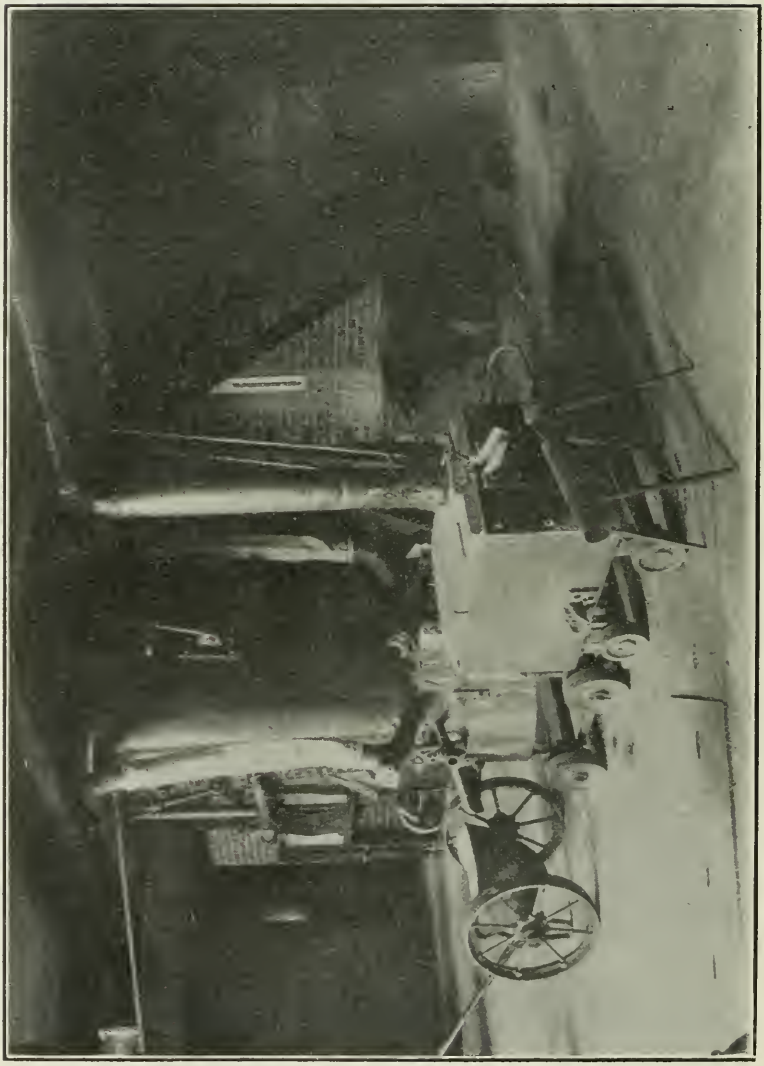


FIG. 5.—Water Jacket Blast Furnace and Fore Hearth, Nos. 62, 63.

Fig. 6.—Cupellation Furnace, No. 64.

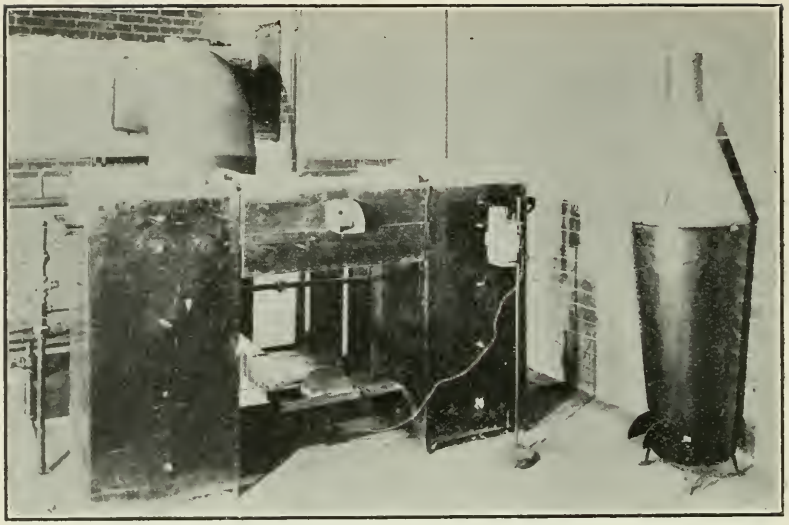


FIG. 7a.—Experimental Open Hearth Furnace, No. 79.

FIG. 7b.—Hand Reverberatory Roaster, No. 61.

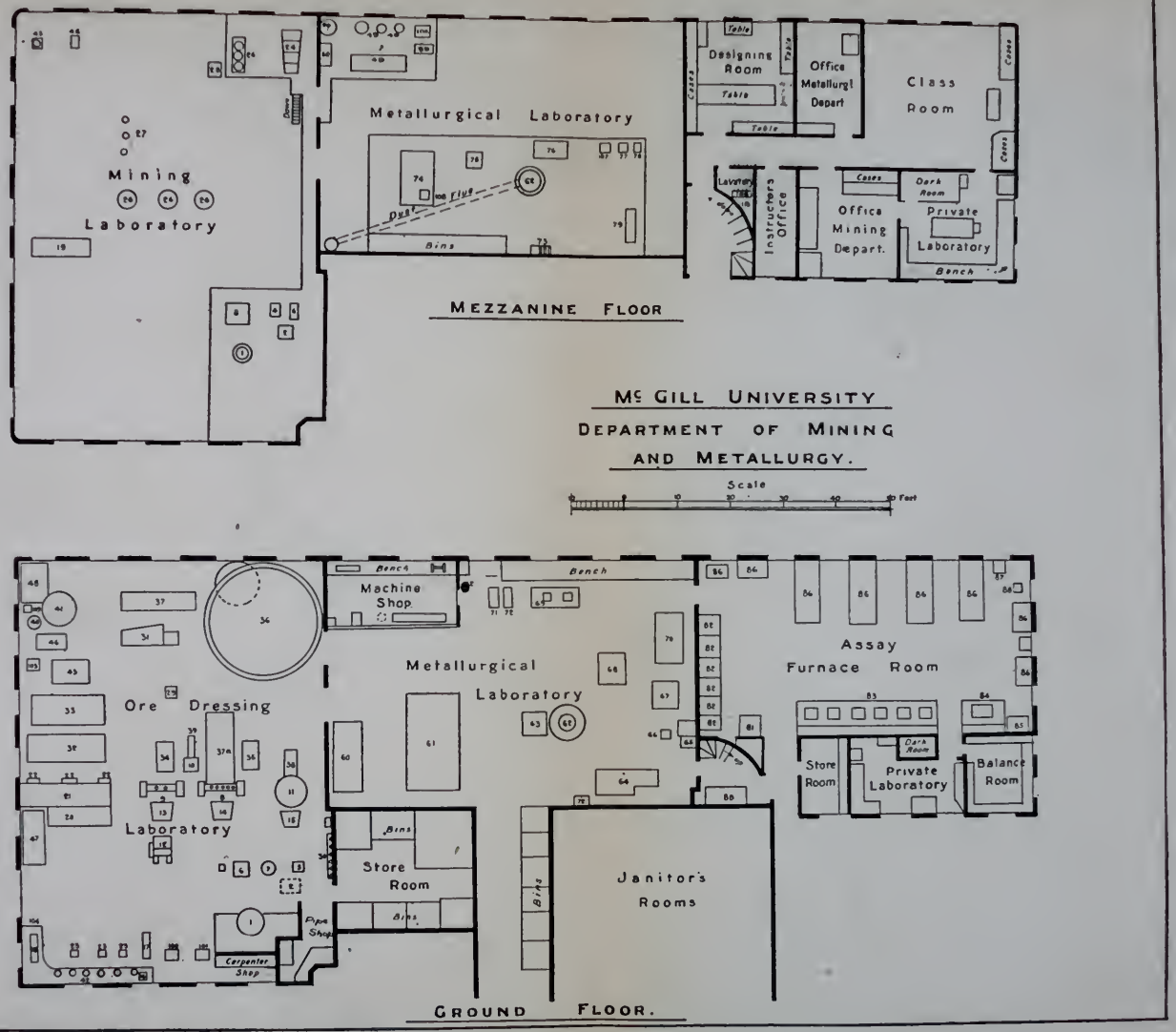


FIG. 8.—Floor Plans of Department of Mining and Metallurgy, McGill University.

KEY TO FLOOR PLAN OF McGILL MINING LABORATORIES.

Ore Dressing Dept.

1. Comet Crusher.
2. Dodge Crusher.
3. Ball Mill.
4. Sample Grinder.
5. Roller Jaw Crusher.
6. Hydraulic Lift.
7. Bridgman Sampler.
8. Five Stamp Battery, 600 lbs.
9. Two Stamp Battery, 1,000 lbs.
10. Steam Stamp.
11. Huntington Mill.
12. Crushing Rolls.
13. Suspended Challenge Feeder.
14. Challenge Feeder, Portable.
15. Tulloch Feeder, Portable.
16. Blake Crusher.
17. Shaking Screens.
18. Shaking Screens.
19. Trommel, with 3 fields.
20. Large Jig, 2 comp.
21. Large Jig, 4 comp.
22. Three small Jigs, 2 comp.
23. Three Vezin Jigs, 1 comp.
24. Spitzkasten, 4 comp.
25. Brown Sizer, 3 comp.
26. Three Large Cone Classifiers.
27. Three Small Cone Classifiers.
28. Pointed Box Settler.
29. Three Brass Tube Classifiers.
30. Seven Glass Tube Classifiers.
31. Wilfley Table.
32. Bartlett Table.
33. Bartlett Slime Table.
34. Small Riffled Table.
35. Small Riffled Table.
36. Evans Buddle.
37. Frue Vanner.

37a Battery Plates, Large.

38. Battery Plates, medium.
39. Battery Plates, small.
40. Amalgamation Pan, large.
41. Settler.
42. Six Amalgamation Pans, small.
43. Wetherill Magnetic Separator.
44. Heberli Magnetic Separator.
45. Centrifugal Separator.
46. Pneumatic Jig.
47. Steam Jacketed Drying Table.
48. Steam Jacketed Drying Table.
49. Cyanide Plant.
50. Elmore Plant.

Metallurgical Dept.

60. Brueckner Roaster.
61. Hand Roaster.
62. Blast Furnace, water jacketed.
63. Fore-Hearth.
64. Cupellation Furnace.
65. Wind Furnace.
66. Forge.
67. Gas Muffle.
68. Gas Furnace Table.
69. Electric Furnace Table.
70. Chlorination Barrel.
71. Power Saw.
72. Grindstone.
73. Drop Test.
74. Electrolytic Table.
75. Power Lift.
76. Iron Table.
77. Polishing Apparatus.
78. Small Blower.
79. Experimental Open Hearth Furnace.
80. Recording Pyrometer.
81. Soft Coal Muffle.
82. Six Wind Furnaces.
83. Six Muffle Furnaces.
84. Three Gas Muffle Furnaces.
85. Draft Cupboard.
86. Seven Working Benches.
87. Bucking Board.
88. Bullion Rolls.
89. Root Blower.
90. Hydraulic Press.

Power, Etc.

100. 15-H.P. Motor.
101. 15-H.P. Motor.
102. 15-H.P. Motor.
103. 10-H.P. Motor.
104. 2-H.P. Motor.
105. 2-H.P. Motor.
106. 2-H.P. Motor.
107. 2-H.P. Motor.
108. 1-H.P. Motor
109. 2-H.P. Motor.
110. Ventilation Fan.

THE COLLIERY MANAGER.

By Wm. D. L. Hardie, Lethbridge, Alta.

The colliery manager, who wishes to count for much on the American continent these days, must be willing to assume much larger and more arduous duties than were ever dreamed of by his predecessors of twenty-five or thirty years ago. The colliery manager of thirty years ago thought and rightly too, that he had to be a man of many parts, some lawyer, some mechanic, some civil engineer, much mining engineer, some miner, some diplomat, much executive, etc., etc., but doubtless, were an old timer to return from his retirement and have to face the problems of to-day he would politely say "excuse me; this is the other—the younger man's day". Before the advent of the mining machine the colliery manager could handle with a few assistants the operations of a very extensive colliery without entailing very great labour on himself and live comparatively the life of a gentleman. But the scene has changed: with the incoming of the mining machine and its complex subdivision of labour have come interminable complications, which keep the colliery manager continually at his wits-end. Concentration of operations and large production is the order of the day. If you want 500 tons per day, get it from one pit; 1000 tons, get it from one pit; 2000 tons, get it from one pit; 5000 tons, get it from one pit. Get cheap coal.

Let us enumerate a few of the difficulties of the colliery manager of the present time as the writer has met them. The demand for coal is increasing and skilled labour or miners are not keeping pace with the requirement, and it is deemed advisable to adopt some means that will enable managers to utilise to advantage unskilled labour that is always more or less abundant in a new country. That mining machines must be tried here at once is the first great obstacle. Miners always have objected and always will object to the introduction of any thing that will make the

operator less dependent upon their skill, even when it will eventually redound to their betterment. At first, they will not touch that hated thing the "iron-man" and they will not load the the coal mined by it.

The plant has perhaps been ordered and is on the ground, the pipes laid down and everything ready, but the men to run the machine and load the coal. An expert runner has been imported and perhaps a helper. Now the manager must be a diplomat and in some way persuade a few to try the machine. A point has been made. But no price is named. The men are trying the work on days' wages and of course, they will not do too much; that would give them away at the final settlement of a contract price. After thirty days trial that point has been reached, and now comes the tug of war. The man who has thought the miner is a fool or a simpleton is here undeceived; but the final outcome at this stage will largely depend on how intimate the manager is with the matter in hand: if he is an expert, two to one, he will make a satisfactory bargain; if he is not familiar with the subject in hand, he may as well at once leave the adjustment to a master hand, skilled either by accident or nature or by long practical and theoretical training.

Let us suppose we have got safely started on a contract basis—price for loading, price for machine running, price for keeping, etc., etc. There are all sorts of subdivisions of prices, and work depending altogether on the conditions that surround the colliery:—what next? Well, you only had one expert machine man to begin with, and if you have no previous experience with this class of work, your progress will be extremly slow, but more than likely if you are far enough along in managerial work to enter upon the negotiations just mentioned, you have been "through the mill" and have at least a few friends amongst the men who run machines, who will be glad to be with you once again for old times sake. Their help will put you in pretty good shape to get a little coal on the new plan and begin teaching a few of the army of "ignorants" to be good runners. The selection of desirable ones from the army, is no easy matter. Every man will not make a good machine runner. Big men do not always make the best "runners"; but everything else being equal, the big man is to be preferred.

If judicious selections have been made as for six months to one year, you will have as many machine runners as you want. Treat them kindly, fairly and firmly, and they will be your friends for ever. When you have men of many nationalities working for you be sure to give them all their due proportion, because as a general thing, loaders and machine men of the same nationality get on best together.

You have now to decide what proportion of labour will give satisfactory results. In this, you will have to be careful, weigh the machine runners' capabilities as a cutter, and proportion his district to suit him. After a time it will be discovered there is an average cutting ability in your colliery governed by the class of men and the conditions of your seam, and you proportion the number of loaders to a machine accordingly in a general way. But some cutters will always be better than others, and you must not retard them, but give them extra loaders to keep them going. On the other hand, you will have a cutter (machine man), not up to the standard, in which case you cannot make the loader suffer. Lop off a loader so that he can cut well and deep for those left to him.

There is another point: each machine will be double shifted and perhaps treble-shifted. In either case it becomes necessary to tell off men to "butty" each other who are of equal ability and suitable temperament to be congenial to each other. If you do not manage this, there will ensue numerous difficulties. Even thus, you will have some trouble, because different men run with a different stroke, even when of equal ability as machine men, and a machine is somewhat like a man, and as is well known, it does not readily accommodate itself to changing conditions. If the machine has pounded through a whole shift on a long slow hard stroke, it dislikes to get down to 200 short strokes in a minute and will very probably make trouble for the second runner. Have a little patience all round and you will presently strike the happy medium. Always be a man, sticking up hard for your ideas and your own rights and those of your company, while steadfastly seeing that your workmen's rights are also properly conserved. Don't be afraid to get angry at the right time.

The miner who has become the loader may also make trouble many times. Conditions are so different. When he went into his coal face in the old days it was all his own for the day and he could handle it very much as he liked with the little restriction put on him by the law and the boss, but now he is dependent upon the machine man, and so long as he is, kept cut up, he does not feel his dependency; but the moment he runs out of coal before the day's work is done, a new complaint is laid before the unfortunate manager, and of course an investigation is necessary. The matter must be straightened out and if possible the recurrence of the like must be avoided as far as possible.

As mentioned before, we have gone into machine mining because the requisite number of skilled miners is not available and unskilled labour must be employed. And unskilled labour if you have not got a stout heart, is a proposition that will turn your head grey and either make you a fit subject for a lunatic asylum or put you in a premature grave.

In the beginning you may have had a voice in the selection of the plant that is in your charge, or may not, but as time moves on you must have a voice in these matters, if you are to be successful. It may be grudgingly given you but it will have to come or a change, but a wise manager will soon have the voice and most quickly if he is familiar with machine mining.

You will find yourself eternally and everlastingly figuring on the capacity of your compressors, your pipe lines of all sizes, receivers and the laying out of the workings and properly proportioning the whole arrangement. If you had no hand in the choice you may find your pipe sizes badly arranged for your work. But in such a case you cannot help yourself; but your theory of friction of flow in pipes etc., will be taxed to its utmost to make the best arrangement with the size or sizes of pipe that they started out with. Even if yourself started in with the plant and had a voice in the one selected, it may be that the output increased by demand to a much larger figure than you ever dreamed of, and the extent of working may run out miles where half a mile was formerly figured good practice. Apply your knowledge now of pneumatics to the fullest. If it is not good, make it good or you will be a failure in the estimate of your employers and men alike. They both revere the

man who overcomes the difficulties as they present themselves. As they see you struggle with these things at first they sit back, look on and wonder if you will overcome them. If you are resourceful and competent and meet difficulties one after another successfully they wonder no longer but go on with perhaps the remark: "He makes every thing stick he tries and this will have to stick too, because he says so."

Be patient, resourceful and energetic.—Energetic both physically and mentally but especially mentally. Concentrated thought is absolutely necessary to success in any line. Men may say so-and-so has a "snap" when in reality he is the hardest worked man in the community. His light physical exertion causes the misconception. He is a mental worker and leads the way. It is easy to follow the trail when the hunter has blazed the way.

To be able to plan and lay out the mine so that the subdivision of labour will give the best results in every way will require the mine plan to be kept up to date, i.e., surveyed every three to six months; and the author finds that a six monthly survey made by himself keeps him more immediately in touch with every detail than a great deal of running around the mine, although much mine travelling is necessary to keep all one's under officials up to the mark. A little neglect here and a little there for a while will run into a broken system that will show up very shortly and will require some trouble to get it up to efficiency again. Eternal vigilance is necessary to keep out of the clutches of the law and maintain operations in an efficient condition. You have to keep at it night and day. The engineer and fireman on night shift are apt to think they have the right to nap. This sleep will mean low air pressure at night and objections from the machine runners. Get all the tell-tale appliances, such as Bristol gauges, fan clock work gauges, etc., that you can, but do not trust to these absolutely. See the men at work once in a while at all hours, from 6 p.m. till 5 p.m. by dropping in when not expected. They'll be looking for you and cannot sleep because they are on the lookout.

Now we have to encounter the General Manager or Board of Directors. Machine mined coal in the majority of cases means the very extensive use of powder which means larger

volume of air; the working pieces travel so fast that it soon means larger fan pressure, and very soon you have to go and demand, not ask, for a larger fan, if this was not considered at the commencement, and you will have to be able to state the class and size of a fan that will meet your requirement, making liberal allowance for a harder duty. You may have to go a bit further and have a word to say about electricity.

In all of these you must have a knowledge that will prevent the manufacturer palming something off on your company which, while it may be good stuff, may not be suited to your conditions. Here is often the place where we have not got strength enough to win out. You must not place yourself too strongly in opposition to your General Manager on any subject, and if he is persistant, it may be necessary to acquiesce or resign when either is a very unsatisfactory result, but authority is one of the necessary conditions of modern developmentsin industrial affairs.

Now it will be said the colliery manager's numerous difficulties have all been told. Not yet. The roads are now getting long and the old time horses or mules are getting in the way of each other. They cannot haul the coal and what is worse the hauling price is getting too high. You must get mechanical haulage installed. You go again to the General Manager with a hauling proposition of $20,000.00 to $30,000.00. It will not be easy; but you must keep at it in season and out by argument backed by figures and experience of others, if you have not had it yourself, until you get what is required, and your out-put, after many difficulties, will climb up surprisingly. Don't forget that the installation of hauling machinery is one of the most trying and nerve destroying undertakings in an engineer's or colliery manager's life, especially if in a new district where it is impossible to get the advice of others. Things you expect the uninitiated to do off-hand you will find require from three to six months to teach him But your hour of triumph will come and that first moment will repay you for all your mental agony.

Your triumph will be well deserved. If you have gone carefully into all the necessary details of all the different systems of haulage that will enable you to make the best selection for the condition of the colliery, you must have done much hard work.

If you have grades that are over 2% or 3%, traction haulage, outside of the neck and pinion, is not to be considered, but if the grades are less you will have a wider range of choice. You may consider electric locomotives, compressed air locomotives, main and tail rope and endless rope. But which one of these will be the best will require your best judgment and a wide range of knowledge of electricity, compressed air, steam and mechanics and to do justice to the two methods of hauling by ropes you will require a fund of knowledge about wire ropes. To simply take a manufacturer's catalogue and select a rope is a poor excuse for knowledge on the subject and will surely be misleading if you have to depend absolutely on that source of information. There are ropes and ropes, manufacturers and manufacturers, who all have their little "tricks of trade". This remark is now especially true of the manufacturers' agents who are themselves not always too well posted on anything but the prices of the various qualities and sizes, and if the purchaser does not know exactly what he requires the low price of a given quality may be so attractive that it will be his undoing in as much as he may get a rope that is not suited to his requirements. A very careful selection of the right quality and size with the proper direction of lay and length of lay in the strand and in the rope must be made. A variety of combinations may give the same satisfactory result but the selection of the combination requires a wide knowledge of the subject on hand.

On the matter of traction haulage by electricity or compressed air, such a detailed knowledge is not quite so essential, because it is bound up as a whole more closely in the work of the expert upon whom we have to depend more or less, but at the same time there is much general information which the colliery manager must have, because after the expert gets through with the installation the operation will be under the direction of the Colliery Manager. The larger his fund of knowledge on the subject the more valuable will be his supervision. The man who knows things cannot be imposed upon and is never helplessly dependent upon another. This knowledge breeds wholesome respect for his authority.

The power plant generally will in itself furnish lots of food for thought and the expenditure of ingenuity. With a view to

the use of the waste coal of the colliery, the manager will be required to make some nice calculation to arrive at the boiler requirements and to use good judgment in the selection of the boilers to be used, if it is left to him; but in any case his knowledge of boilers will necessarily have to be quite extensive if he is to get good results. Careful and well considered steam piping is not the least important matter either.

The manager's knowledge of theoretical mechanics must be so well grounded and seasoned with practice that he can compute to a nicety the size of cylinders required in his hoisting engine, size of drums, size of rope required and many other details. In fact he should be able to determine correctly the proper size of any steam driven engine, be it hoisting engine, electric engine, compressor or pump.

The matter of hot water feed for his boilers too, must receive much attention, because by delivering the feed water at about 200°F he will get all the way from 10% to 50% more capacity out of his boilers, depending of course on the class of coal used; but on collieries it will be most generally the class of coal that will give the higher percentage. In actual practice the author has 1200 normal H.P. in boilers, the capacity of which drops 40% when the feed water is reduced from 200°F. to the ordinary temperature of cold water. The boilers being fired with fine coal with much dirt in it, at no time give more than three-fourths of their normal power.

The questions of firing and draft will require a knowledge of chemistry and ventilation on a rather different scale from that taught in college, but happily the fundamental knowledge gained in college will enable one to shortly and easily acquire the information desired on these points. But they are far too important to be neglected and are growing in importance every day.

The proper and systematic handling of coal to the boilers and ashes from the boilers and the drainage of the whole plant, to prevent slush and uncleanliness, will come in for a due share of consideration, as will also the erection of proper buildings to house the boilers, machinery and workmen.

As the years go by, more and more attention is paid to washing coal and separating the different sizes; and there are no machines in use from the elementary trough washer, which gives good

enough results where refinement is not essential, to the elaborate washery that cost $150,000.00. These latter are usually erected by experts and contracting firms; but as with other things when erected and turned over, the colliery manager bears the responsibility of keeping it going and of its doing satisfactory work. To acquire a good thorough knowledge of washing is not so difficult a matter as many other subjects in colliery management. To be able to design your own washer or breaker is not, these days, considered too much to require from the colliery manager.

While washing and mechanical screening go on with a view to putting the coal in the most saleable condition, be the coal anthracite or bituminous, the screening and washing is frequently entered into with the view to preparing an inferior bituminous coal by ridding it of impurities for making coke.

Another subject is that of coke making. The largest responsibility in this respect is in the selection of the proper oven to coke the particular coal on hand. The chemistry of coal and coke gives valuable theoretical information; but the practical end in this particular part of the colliery manager's duty is the important one. The more practical observations he makes, the more intimate will he become with this branch of his possible duties. But in this as in all the other departments he must know how, if he would be successful. He will have his burner and the several other subordinates, but this only makes his authority weaker if he does not know how.

This brings us to the tipping arrangement and that part of the cleaning of the coal, which is not done by the miner below, nor by the washing and sizing of the finer coal.

Modern tippers are various in form and shape, frequently peculiar to a particular district, but the principal object of its construction is to pass the coal from the mine cars over screens and picking belts, where the larger pieces of slate and stone are removed by hand picking, into the railway car. A tipper or bank head, as it is sometimes called, may be any thing from a very simple arrangement to a very complicated affair depending altogether on the conditions bounding the colliery, from which it will be readily seen that the more a man has visited and seen on

other works the larger will be his mental range in this particular line of structure.

This paper may seem to cover a very wide range but the half has not been mentioned. Diligent study, application, and observation will equip a man so that he may attain such a position in these days, when the "young man" is in demand, between the age of thirty and forty.

Experience being absolutely necessary there is a long list of minor positions you will have to fill to get the necessary experience Become a member of all the mining institutes your income will afford, read the transactions carefully, get all the best books, mining and mechanical papers within your your reach and read them carefully. Make your mind a mental index, i.e., train your mind to recall the particular book or paper containing a certain article, so that when you need it you can look it up; or what is better still begin early to compile an index and keep it right up with your ever increasing library remembering all the time that

"Index learning turns no student pale
"But grasps the eel of science by the tail".

Visit every colliery within your reach, for colliery management as it is represented to-day by many of our best collieries, has been the result of slow evolution. You will see much in a few minutes, if you train your mind to be receptive, to take in at a glance many little things that have been gradually evolved by long laborious thought on the part of many minds. The small part that only one man plays in evolving the great whole is infinitesimal but it all can be taken in at a glance by the keen observer; and the more study you give the stronger will the matter be impressed on your mind.

Finally, let me say, we all cannot attain success, as we measure it, but we can all deserve it.

THE INFLUENCE OF VARYING DEGREES OF SUPERFUSION IN MAGMATIC DIFFERENTIATION

By Alfred C. Lane, Lansing, Mich.

The grain of Igneous Rocks depends upon many factors, some of which, such as the chemical composition of the molten mass, chemical reactions therein, and the escape of certain constituents by relief of pressure, are referred to in the Michigan Reports.* We might also add the varying degrees of liability to supersaturation, and the peculiar relations of the crystallizing minerals thereto. But the rate of cooling is always an important factor, and other things being equal, as Lawson pointed out, the faster the cooling the finer the grain. Often this is so dominant as to be practically the determining factor, and the grain is found to be, in even a numerical way dependent on it and thus on the distance from the margin. This is true for instance of the ophitic or luster mottled melaphyres which are the common type of rocks in our copper-bearing series, and by studying the indications of grain I have been able to save thousands of dollars in guiding explorations for those amygdaloid beds or lodes, which represent simply the scum and froth at the tops of successive lava flows.

The rate of cooling, and consequently the grain, varies, however, greatly in different parts of a cooling sheet or belt, according as the temperature at which the rate of cooling, which we will call the temperature of consolidation, is high or low. In reality of course, the consolidation does not take place at a definite temperature, but through a range of temperature, which may be relatively narrow.

If the temperature, or range, of consolidation is very near that at which the sheet was injected the rate of cooling will be slowest at the centre, where the grain will be coarsest, and most rapid at the margin. But if the temperature of consolida tion is just half way between that of the injection, and that of

*Vol VI. Part I.

the country rock before the instant of injection, the rate of cooling is slowest at the margin. If it is a little higher, the slowest cooling is only near the margin and as the temperature of consolidation rises the belt of slowest cooling and coarsest grain is farther and farther from the margin and less and less marked. Its position is thus an index of what we shall call the degree of superfusion, the ratio of the temperature of consolidetion to that of injection, supposing that of the country rock to be zero. I denoted it as $\frac{v}{u_o}$. In a rough and general way, not entering into mathematical refinements* from near the margin the rate of cooling decreases for a short distance, and the coarseness of grain increases proportionally to the distance. Crystals formed before the sheet came to rest must of course be left out of account. The size of grain at the centre relatively to that which would obtain if this rate of increase at the margin were continuous depends on the degree of superfusion, being less the hotter the injected rock was at the time of injection.

Making certain assumptions we can express the relation graphically and numerically as given in the diagram.

Let E be the grain at the centre using linear dimensions, or diameter of magnifying power, C' the rate of increase at the margin, and c the whole zone which should be supposed affected, including not only the width of the sheet but a certain amount of contact zone, which is only a secondary correction fortunately, since it often has to be guessed at. Then if in the figure given we take $\frac{E}{C'c}$ as the vertical ordinate of a curve corresponding to the contact zone we have assumed, the horizontal abscissa to the point gives the superfusion ratio. The curve only covers a superfusion ratio greater than 0.5; if it less than that the grain is greatest at the margin and decreases toward the centre. The lower it is the less the difference.

Let us illustrate now by a little example,† taking one of the

* A fuller treatment will be found in Volume VI of the reports of the Michigan Geological Survey (Part I, Chapters IV and V), and Annual Reports of the State Geologist of Michigan for 1903, p. 205, and 1904, pp. 150, 163, and. Vol. XIV of the Bulletin of the Geological Society of America.

† I may say that I know the field relations of these rocks only through the writings of Adams and Dresser, not personally. To the latter I owe the chance to examine the specimens. In our own Michigan rocks of course it is different. I have seen them not only under the microscope and in the drill core, but in the field and mine.

Canadian rocks, a little two inch dike cutting essexite from St. Bruno Mountain, Montreal. Take, for instance a section cut clear across it. A few big slightly corroded crystals of augite are sailing along in the middle of it like logs in a stream. But leaving these aside it is still not hard to see the finer grain at the margin with the naked eye. By comparing the section at the margin magnified seven diameters with the section at the centre seen at the same time side by side through an Abbe camera lucida is found to appear of the same coarseness about one tenth the way in —0.1 inch from the margin. The rate of increase then is;

$$C' = \frac{\frac{E}{7}}{0.1 \text{ inch}} = \frac{10}{7} E.$$

Now c=some 2 + inches and so:

$$\frac{E}{C'c.} = .35\text{-}.$$

Turning to our diagram, we find that if we take no contact zone $\frac{v}{u_o} = .98$ or if we take one an inch wide on each side, while $\frac{E}{C'c}$ will be but half as much we have to use a lower curve and $\frac{v}{u^o}$ is still .92.

In any case the temperature of injection of the little dike was not far above that of consolidation. This fact is in entire harmony with the presence of not badly corroded, easily fusible, augite crystals floating around in it.

In the same way we may work for any rock, comparing the grain as near as we can go to the margin, without being affected by irregularities due to eddies and stirring in flowing, and comparing it with the centre. Generally speaking, in surface flows, and in some small intrusions, not much superfusion has been observed.

With the large intrusions, however it is different. There is generally a considerable belt of uniform grain at the center, and often a well marked belt of coarser grain at or near the margin. Take the same Monteregian province from which this dike comes. Mount Johnson as described by Adams* has coarser rocks near the periphery of the main essexose mass, though here the phenomena are complicated by phenomena of chemical variation to which we shall return.

* Journal of Geology, Vol. XI, p. 254.

An even better illustration is that cited by Dresser in his report on Shefford Mountain, though again the phenomena are doubtless complicated with chemical changes.*

"Along the original contact zone the dark minerals are in increased amounts and the texture of the rock becomes variable", quite as might be expected if the superfusion ratio is near .5 for then slight differences in that ratio, corresponding to slight differences in the temperature of the country rock, fusibility of the magma, etc., may produce great differences in the grain.

In a section exposed for a time during the construction of an aqueduct from Couplands Lake to the town of Granby the contact facies were well shown, and Dresser has been kind enough to send samples to me.

A. "For forty yards from the contact the rock was fine-grained, and about one half of it was made up of black hornblende."

The sample sent representing this forty yards (*A*) shows *hornblende* prisms up to 5 or 6 mm, generally about 4mm x 0.3mm; irregular altered *biotite* leaves about 1 to 1.5mm across, *iron oxides* and *sulphides* from irregular secondary granules, .02mm in diameter, up to .6mm, but on the whole finer than in *B*.

Apatite, 0.8mm x 0.065mm, is much finer than in *B*.

The (soda) *feldspar* laths are about 2.5 x 1mm, but there are none of the early sharp plagioclase laths older than the hornblende.

The general impression is that it is but one third or one fourth as coarse as *B*.

B. "By a sharp transition the rock then became exceedingly coarse for the next thirty yards and the proportion of hornblende was somewhat increased". "The hornblende crystals were seldom less than half an inch in the smallest dimension."

The hornblende is also distinctly poikilitic, or ophitic, (see page 16 of Dresser's report), in large patches 6 to 7mm or more across, and enclosing lathshaped sections of plagioclase.

* Report on the Geology and Petrography of Shefford Mountain, 1902, part L, Annual Report, Geological Survey of Canada, Vol. XIII, p. 14.

This is very suggestive in the consideration of the occurrence of apparently primary areas of sulphides, pyrrhotite, intergrown with magnetite.

The *feldspars* enclosed in the hornblende are smaller (0.8 mm x 0.1.6mm) than those outside which are about 2.2mm long, on an average, but run up to 3 or 4.

The particles of *ore* average about 1mm in diameter, but run up to two or three times that dimension.

The *apatite* runs from 0.8mm long up to 2.5mm long, and 0.1mm across, being in s ender needles.

This is apparently the belt of magmatic segregation in this section.

C. "It next returned quite abruptly to the fine grained type for 210 yards", and this was represented by specimen *C*.

The *hornblende* is indeed finer than in *B* but it is not in idiomorphic prisms as in *A* nor in patches as in *B*, but in corroded shreds, from 1 to 4mm long.

The *plagioclase* is coarser than in *B*, averaging perhaps 2.6mm parallel to *M* but running up to 3 to 5mm. It is idiomorphic against a green pyroxene, like that elsewhere described by Adams and Dresser, some sort of a diopside.

The *ores* are about 0.75mm in diameter, fully as coarse as in *B*.

The *apatite* is about 0.8mm x 0.08mm.

The *biotite* seems to be corroded too, having margins dotted with iron oxide, but is 2.5 to 3mm in diameter.

D. The rest of the way to the lake was occupied by a rock, Specimen *D*, in which the *hornblende* and corroded *mica* are 2 to 4mm in diameter, the *plagioclase* 3 to 5mm long, the *ores* almost wholly magnetite, from .7 to .3mm in diameter.

The *apatite* is about 0.1mm across as usual.

Now the grain in *B,C* and *D* does not vary much except in the hornblende, and a similar coarse ophitic band of pyroxene was found in the Medford quartz diabase near Boston.

A, however, is distinctly finer, and although we cannot unfortunately determine the exact direction of the contact surface nor distance of *A* from it, it seems clear that the rate of increase must have been such that continued to the centre the grain would have been far greater for all the constituents than

it is, the hornblende at 280 yards from the contact something like 28mm or more and the feldspar near 20mm. Consequently we may infer that the superfusion ratio was just a little above .50, for the hornblende anyway, and the rock heated much above the consolidation temperature.

Moreover the feldspar seems to have a somewhat greater superfusion ratio than the hornblende, indicating that its consolidation temperature was on the whole higher than the hornblende.

But this superheating has had other effects of especial interest to us who are interested in mining. It has apparently allowed time, and promoted mobility, so as to allow a separation of different constituents. Probably *A* may be conceived to have solidified so rapidly that no marked splitting took place in the early period before the contact zone had heated much. *B* represents the zone of maximum grain, and slowest cooling. Here cooling, before and during the time of consolidation, took place so slowly that there appears to have been time for segregation of certain constituents. Which of the various ways in which such splitting took place was efficient we shall not stop to discuss now, except to remark that if it was due to settling of solid particles under gravity, or actual crystallization out around the walls of the mass still liquid the action must have taken place after the molten mass had begun to crystallize, presumably at temperatures not far above that of consolidation, and perhaps mainly in a marginal belt.

Now in *B* the iron ores, including sulphides, seem to have collected, and these, or some other constituents, increased the amount and prolonged the period of hornblende formation until it is later than a good deal of the feldspar.

Conversely the rock farther in, robbed of its hornblendic constituents, was enabled to attack the hornblende, which (as we see from the margin *A*) formed early in the normal magma, corroding it and reducing it to mere shreds. In that part of the rock represented by *C* and *D* there was a relative accumulation of calcium, which tended to produce pyroxene rather than hornblende, and a feldspar containing more lime, and therefore of higher fusing point, able to crystallize and actually developed, not sooner in point of actual time than the soda feldspars of the

margin, but at a higher temperature, and at an earlier stage in the consolidation of the rock.

If we are right in these inferences from the sections the fact and degree of superfusion has a very important bearing on the splitting of this rock, and on its magmatic differentiation, which is sometimes at any rate the first step towards the concentration of ore bodies.

There seems no doubt that the Sudbury nickel bearing was similarly superfused, although it is not possible to put it in the same mineral form.

Superfusion may however occur without splitting, depending on the constitution of the molten rock and how near it approaches a eutectic. From Daly's notes on the Moyie Sill it could be pretty certainly inferred that that was highly superfused, though not so much differentiated.

The following are a few notes on his specimens:—

1137—Analysis E, 15 feet from the upper contact, seems to be a fused or recrystallized quartzite of the country rock, as well as—

1138—Analysis D, 40 feet from the upper contact.

1139—50 feet from the upper contact.

On the other hand—

1140—Analysis C, 200 feet from the upper contact, seems to be within the original magma.

1140—Analysis B, is near the middle and is apparently finer grained than

1144—200 feet from the lower contact, in which the hornblendic mineral is extra abundant, and in 2 to 3 mm patches, coarser and more abundant than at the centre, and therefore corresponding faintly to B of the Shefford Mountain section.

1143—30 feet from the lower contact, analysis A, is distinctly finer grained, the dimensions of the constituent particles being about 0·5mm.

Obviously the marginal increase of grain, counting from the undoubted lower contact would mean a much greater central grain than really exists, and we may assume a superfusion, but the magmatic differentiation seems to be confined to a slight

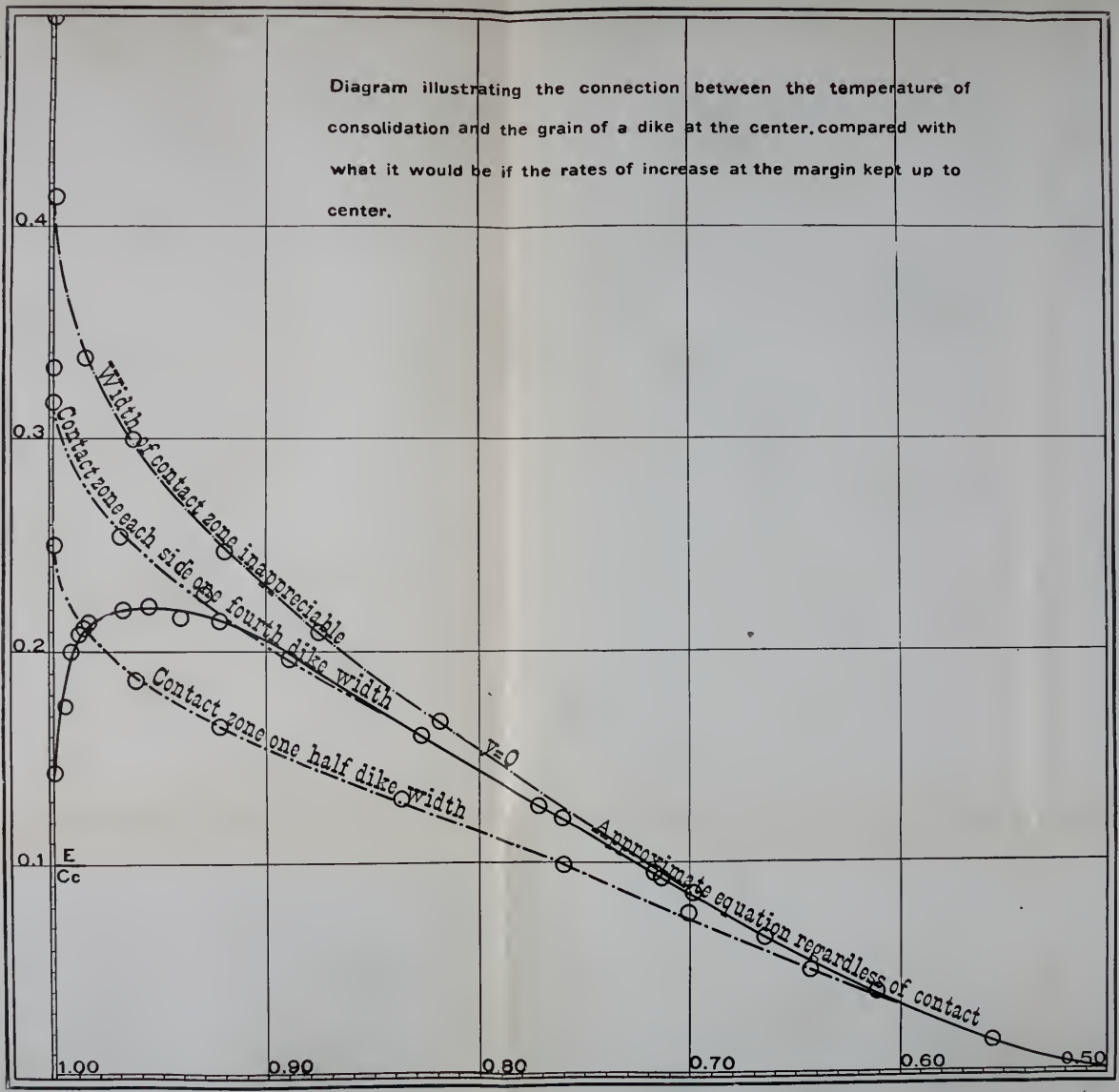


Diagram illustrating the connection between the temperature of consolidation and the grain of a dike at the center, compared with what it would be if the rates of increase at the margin kept up to center.
0.4
0.3
0.2
0.1
E/Cc
Width of contact zone inappreciable
Contact zone each side one fourth dike width
Contact zone one half dike width
V=0
Approximate equation regardless of contact
1.00
0.90
0.80
0.70
0.60
0.50
← V/u₀

accumulation of darker minerals towards the bottom, and a considerable accumulation of feldspar solvents at the top.

In conclusion, the subject should not be left without suggesting some parallelisms between the specimens discussed, and those described by Adams from Mount Johnson.

According to our reading of the facts, *A* represents the original composition, too quickly cooled to split much, and may correspond to the pulaskite laurvikose of Adams (diagrams 1, 2, and 3, of his figure 4). The zone of maximum grain represented by *B* may correspond to a zone mentioned by him* which is characterized by very large crystals of soda feldspar, rather than hornblende, perhaps due to some slight after motion of the magma during the relatively long time while this zone was in the process of crystallizing. But he also mentions the high proportion of hornblendic minerals. It may be slightly represented by diagram 4 of his figure 4, while *A* is probably more nearly represented by diagrams 1 and 2.

2. Finally the central residue *C* and *D* appears to be represented by diagram 5, more or less. It is, however, obvious from the petrographic descriptions that Mount Johnson differs perceptibly in the history of its igneous development from Shefford Mountain, and the above comparisons must be taken as suggestive merely.

The main point to be emphasized is the importance of superfusion in the history of the development of a magma, and the magmatic concentration which is the first step in the history of many ore deposits.

The degree of superfusion one can obtain roughly numerically by considering the variation of grain relative to the margin.

* Journal of Geology, XI (1903), p. 275 especially.

ON THE PROBABILITY OF FINDING MINES IN NORTHERN QUEBEC.

By J. Obalski, Director of Mines, Quebec.

Before 1898 the Province of Quebec was bounded on the North by the height of land, and the district was of little interest. It had, however, been traversed by a few explorers and geologists who had noted certain peculiar features. The first of these gentlemen, Mr. James Richardson, of the Geological Survey, had reported in 1870, the existence of iron and copper pyrite, magnetic iron ore, ochre and serpentine, at Lake Chibougamou. Later, in 1885, Mr. A. P. Low, also of the Geological Survey, confirmed this report and recognized the formation as similar to that at Sudbury. In 1903, an adventurous explorer, Mr. Peter McKenzie, resolved to visit the region and investigate the deposits. After a most difficult journey he reached the spot described by Richardson and brought back with him good specimens of amianthus, chalcopyrite and bornite, magnetic iron ore and various rocks showing the geological structure of the region.

In the summer of 1904 the author undertook an exploration to verify these reports, and has since published the results in his official report for 1904. He confirmed all that Mr. McKenzie had found, and was fortunate enough to detect the presence of gold in a large quartz vein ; he also perceived that the band of serpentine was of considerable extent.

Mr. J. E. Hardman, acting for a company formed by Mr. Peter McKenzie to exploit the deposits, visited the region in the summer of 1905. His opinion of its possibilities has been published in the August and September numbers of the *Canadian Mining Review* for that year and in other periodicals. This opinion is most favourable, especially with regard to the gold, and carries the more weight as Mr. Hardman is well known as an authority in this particular line.

In the same summer Mr. A. P. Low was exploring the district for the Canadian Geological Survey at Ottawa. Other explorers were travelling through the country at the same time

with results satisfactory enough to result in the formation of several companies to exploit the region.

The Quebec Government has resolved to subsidize a winter road or trail so that provisions may be more economically transported. The district may then be considered as likely to be developed, but its products can only attain their full value by the construction of a railway.

An examination of the geological map published by Dr. Robert Bell in 1904 shows that the area recognized as Huronian at Lake Chibougamou, seems to be but a small portion of the formation which stretches in a south-westerly direction to Lakes Abittibi and Temiscamingue, and beyond to Sudbury and Lake Superior, and which in certain parts is so richly mineralized.

Following the valley of the Bell River, which is only a tributary of the Nottaway, we see this formation represented on the map as stretching North and South about 140 miles, affording a considerable field for prospectors.

This territory may remain valueless for some time on account of its inaccessibility ; but it may be traversed by the Grand Trunk Pacific, so that it is to be hoped that in a few years it will be much easier to reach.

The Geological Survey has discovered interesting indications near Lake Abittibi and deposits of minerals of commercial value may be expected there. At Lake Temiscamingue the neighbourhood of the rich mines of Cobalt encourages searchers on the Quebec side.

The outlook then for prospectors between the height of land, James Bay and Lake Mistassini is encouraging. The country to the north-east of the lake has been explored by Mr. A. P. Low, who reports considerable deposits of iron, but it probably will not be opened until later.

The asbestos found at Lake Chibougamou resembles that of the Eastern Townships and occurs like it in a green serpentine. The gold has been found both free and in the copper pyrite in a vein of quartz forty feet thick, where it averages about $10.00 to the ton. The copper occurs as bornite and chalcopyrite, two very rich ores, and a small amount of nickeliferous magnetic pyrite has also been found.

In view of the prospecting which will certainly be done this

summer, it might be well to recapitulate the principal points of the mining laws of the province.

Mines on Crown lands and on those not patented before the 24th of July, 1880, belong to the Government of the Province of Quebec.

Prospecting on these lands is free, but gives no rights. Licences are issued by the Government, granting the first right to purchase the land named on the permit.

Any mine discovered may be marked by stakes and rented from the Government at a given annual rental ; it can also be purchased for a price fixed by law.

The Bureau will furnish any required information, and estimate the value of their discoveries for prospectors.

NOTES ON A DEPOSIT OF NICKELIFEROUS PYRRHOTITE AT MALACHITE POINT.

By Armand Muscovici.

Malachite Point is situated on Lake Chibougamou near Paint Mountain.

The first discovery made there was a small deposit of copper, occurring as chalcopyrite and bornite in a quartz gangue. It occurs in a rock which Mr. J. E. Hardman has described as an altered gabbro, and which Mr. Richardson of the Geological Survey calls a chlorite schist. The hope of finding a larger deposit led to the following up of the small one, and brought to light after a few blasts this variety of magnetic sulphide of iron called pyrrhotite, which the author for the first time established as nickeliferous during his visit of exploration in 1905. The pyrrhotite is intimately mixed with the chalcopyrite, and the formation identical with that seen in Sudbury by the author. The pyrrhotite occurs in the form of four small veins from one half to two and a half inches in width and apparently of little depth—not more than three or four feet from the surface.

An analysis of a sample taken from this deposit made by the author in the laboratory of Mr. Milton Hersey in Montreal, gives:—

Copper	12.03%
Nickel	0.39%
Cobalt	distinct traces.

It has been thought important to bring this discovery to the attention of the Canadian Mining Institute, not because of its commercial importance—for from the above analysis the proportion of nickel is seen to be too small to be considered commercially—but merely to show that the pyrrhotite is nickeliferous, without considering the future importance of the deposit or the likeness it bears from the geological standpoint to the deposits at Sudbury, Ontario.

DISCUSSION.

Mr. HARDMAN.—For the benefit of the gentlemen who may not have followed Mr. Obalski's reading of Mr. Moscovici's paper slosely, I might say that Mr. Moscovici informed me that the pyrrhotite in no case which he had examined had carried more than 0.39% of nickel. All of you understand that an ore carrying only 0.39% of nickel is hardly an ore under the present conditions of pyrrhotites around the Sudbury District, which run a great deal more than that. At the same time, it is indicative of the possibility of finding them. Furthermore, in a chat with Mr. Low just now, he tells me that this gabbro is a hypersthene gabbro, which may lead to the inference that bodies of norite may be found among this region.

Dr. DICKSON.—Is there any free gold up there at all?

Mr. HARDMAN.—The free gold, which occurs in the large quartz vein in Paint Mountain, is called free on account of the decomposition of the copper which originally contained it. I have no knowledge of the gold found on the other side of McKenzie Bay. There is a small stream coming in there called Rapid River, and just at the mouth of another river there have been three different discoveries, as I am informed, since the date of my visit there, that is, the discoveries were made in August and September of this year. There were also smaller quartz veins, from two to three feet in width, in which free gold was found, but upon questioning my informant, he was unable to tell me whether they carried iron or copper pyrites. If they did, I think one might assume that the gold was not there as free gold, but as the result of decomposition.

Mr. LOW.—I took samples from a number of quartz veins and brought them home; on analysis they did not give free gold.

THE ORE DEPOSITS AND GEOLOGY OF THE SUDBURY DISTRICT.

By Hiram W. Hixon, Victoria Mines, Ontario.

The discussion following the publication of an article on "The Geology of the Sudbury District" in the *Engineering and Mining Journal* of Dec. 29th. 1904, was not strictly according to the rules for scientific discussions, but it served the purpose of showing the pamphleteers that there are two sides to the question. The Canadian Geological Survey has persisted in ascribing an igneous magmatic origin to the Sudbury ores for so long that it came to be regarded as heresy to differ with them.

With the exception of three detail sheets of Snider and McKim townships, all the maps issued by the Department are so inaccurate as to be of little value. The geology is so complex that it would take years of hard work, with a large force, to map it correctly. Roughly the Sudbury District is composed of two ranges of hills known as the north range and the south range, separated by the synclinal valley of the Vermilion River. In these ranges compression and folding have been most pronounced, and subsequent glaciation has exposed the greenstone and granite as corebands.

A detail study of the geology of the country north of the Georgian Bay will show that the entire region was formerly covered by the Huronian sediments, consisting principally of slates and quartzites. In some parts of this large area the Huronian sediments were laid down on granite, while in the Sudbury District they are in nearly all cases lying on, or standing on edge against greenstone cores of the anticlinal folds. The entire region has been compressed and folded until it resembled a series of corrugations. The tops of the anticlinals were subsequently cut off by glaciation and the basement rock, on which sediments

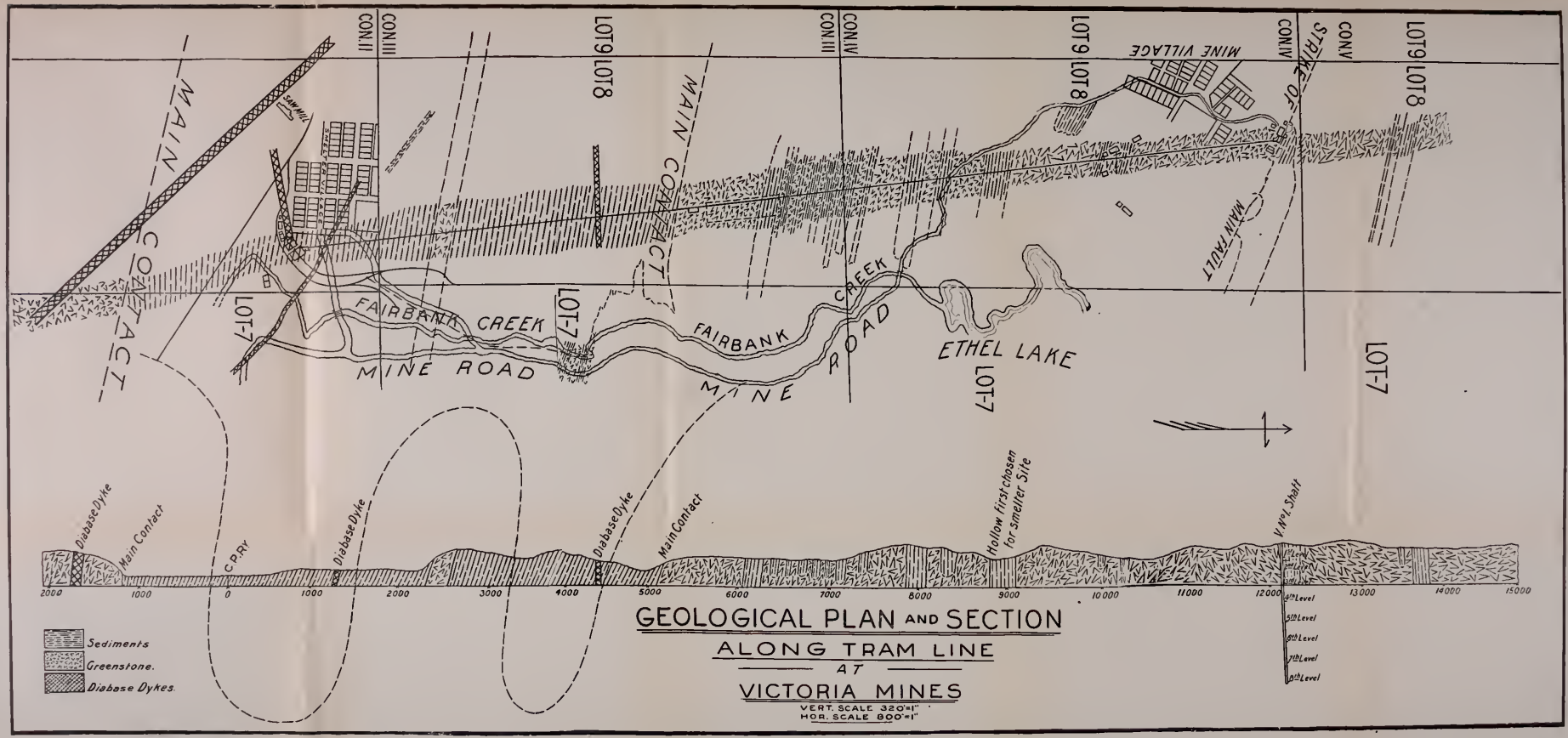
were laid down, has been exposed as parallel corebands with the synclinal of sedimentary rocks between. Referring to the accompanying map it will be seen that there are sixteen of these parallel corebands of greenstone, separated by sedimentary rocks, in a distance of two miles and a half (from the south half of Lot 8, in the Second Concession to the north half of Lot 8 in the Fourth Concession of Denison Township counting northward).

The Victoria Mine ore body is on the north side of the 16th greenstone core on the contact between the greenstone and quartzite. These greenstone corebands are not all of the same width or length, some of them extend through the country for miles as lines of rounded, glaciated hills while others are traceable for only a short distance across the top of one or more hills.

The line of separation between the greenstone and the sedimentary is sharp and does not show any special alteration due to heat. The sedimentation planes are intact, and there are no dikes or offshoots from the greenstone into the sediments, which would be the case if the greenstone were molten when intruded.

The dikes shown on the accompanying map are two miles from the orebody and are entirely different from the greenstone. They cut across the bedding planes of the sediments and in one case cut the greenstone. In the north half of Lot 8, in the Second Concession of Denison, there are eleven known, varying from less than an inch up to 75 feet, in thickness. The conditions of their occurrence indicate that they are younger than the folding. The greenstone does not cut across the bedding planes of the sediments but conforms to the strike of their upturned edges, and is, evidently, older than the Huronian.

All the conditions point to the greenstone being the basement rock on which the sediments were laid down in shallow water. This would show the impossibility of the sulphides separating from the greenstones along the contact unless they could separate from a cold magna under water and rise to the surface instead of going downward by their greater specific



GEOLOGICAL PLAN AND SECTION
ALONG TRAM LINE
AT
VICTORIA MINES

VERT. SCALE 320"=1"
HOR. SCALE 800"=1"

gravity. There are two classes of contact deposits in the district and all the mines belong to one or the other.

1. Contacts between the greenstone and sediments as above described.

2. Contacts between greenstone and granite.

The Creighton Mine of the Canadian Copper Co. belongs to the second class.

The North Star Mine is supposed to be on the same contact as the Creighton about two miles to the north east, but this cannot be positively stated, as there are several parallel granite ridges running through that part of the country.

The greenstone is much thinner in the eastern townships than in Denison. and it lies on top of the granite and on both sides of the granite ridges in the same manner as the sediments lie on and against the greenstone in Denison. The relation between these rocks indicate that the greenstone overflowed the granite and that subsequently sedimentation placed the Huronian series on top of the greenstone. The folding is subsequent to sedimentation, and the orebodies are younger than the folding as proven by there being no faults in the overbodies themselves. If the orebodies were older than the folding they would be broken up and faulted, whereas the mining has shown that the orebodies are continuous and without faults. The difference between the two classes of contacts is simply a difference of depth to which glaciation has gone. This would be governed by the thickness of the sedimentary series as well as the thickness of the greenstone in different places.

After passing below the limit of the greenstone-quartzite contact, the orebodies will, in all probability, follow down along fractures in the greenstone and if followed to great depths will pass through the greenstone and be found on the contact between the greenstone and the granite as they are at the Creighton and North Star. Still greater depth would find them following fractures in the granite leading to the real source of all metal mines, the ingneous core of the earth, from which the occluded steam and gases have brought the mineral wealth to the surface.

I would not expect them to be large enough to profitably work after passing below the greenstone into the granite for the reason that the granite is more silicious and less soluble and would be less easily replaced.

The deposition has been by replacement of the more soluble rocks near the surface. For this reason we find the ores associated with and replacing certain rocks. Replacement in many cases is incomplete and we find all stages from rock with traces of ore to ore with only traces of rock. The quartzite has not been much affected and the ore cuts off sharply when it comes in contact with it, or with the granite, simply because the greenstone was more soluble. Regarding these orebodies as the remains of the larger ones which existed before glaciation removed about 3000 feet of the surface, they are deep mines before being worked.

The theory of the hydro-thermal origin of orebodies is as old as the study of geology. It has however been in need of a discovery to strengthen it until Prof. Arrheneius, followed by Prof. Suess and others, announced their belief that the true sources of all hot waters was the occluded steam extruded from the igneous core of the earth, that such waters were distinct additions to surface waters.

In the *Engineering and Mining Journal* of June 29th, 1905, I gave the result of some experiments with obsidian, by which it was changed to pumice, at high temperatures. The same facts are recorded in Humbolt's Travels relative to the obsidians of Teneriff. I therein stated my belief that the water of combination in igneous rocks was forced into the igneous core of the planet while it was in process of formation. The hail of solid matter towards a common centre would force some of the gaseous envelope into the igneous core. As this gaseous envelope would consist of incandescent steam with all the other gaseous elements and combinations of elements it would naturally follow that the extruded gases around volcanic vents should contain them. It has been demonstrated that volcanic gases are about 99% water, the balance being HCl, CO, CO^2, SO^2,

H^2S, etc., (Dana's Geology). Hot water or steam under high pressure with the addition of such strong chemicals as these and plenty of time; with the expansive force of the gases extruded from the igneous core behind them, can do anything that has ever been done in the way of ore deposition.

It is not necessary to call on nature for a violation of her laws in order to account for a simple orebody. In order to dispose of the magmatic segregation theory it is only necessary to call attention to the fact that if these orebodies were separations like matte from slag, that the line of separation would be a flat surface in the same way as the separation, between matte and slag in a pot is always a flat surface and sharply defined. The fact that they have no flat surfaces is sufficient evidence that they were not formed in that way. The magmatic segregation theory has survived the witchhazel and the divining rod but its end is as certain and the day is not far distant when it will have no place in the literature of mining geology except as a stage of its evolution.

DISCUSSION.

Mr. HIXON.—Before attacking the teaching as regards the nickel deposits of the Sudbury District, you naturally want to know what it is all about. What bearing has it on the mining of these ores and of what use is it whether we conclude that they have one origin or another? The theory has a very important bearing on the equipment of the mines themselves as has been proven in our own case. We were originally expecting that the ore deposit would be very shallow and consequently this particular mine, the Victoria, was equipped with a hoisting engine to go down 500 feet. We were advised by Swedish experts, who were said to know all about these deposits, that the ores would probably go down 300 feet. We are at present down 800 feet and are still in ore; so that it shows you that if we are to consider the teaching that the deposits are separations from magma and near the surface, one kind of equipment would do, while if they were of replacement

origin, emanating from very deep sources and continuing to great depths, we require another kind of equipment. I have no quarrel with anybody's opinions on this subject, but I think the question is of sufficient importance to deserve more attention than it has heretofore received.

Dr. BARLOW.—My views on the origin of the nickel-copper deposits of the Sudbury district are no doubt well known to all present who are interested in this subject, and need not be emphasized at this time. Dr. Dickson has already stated that he will present a paper on a closely allied subject, after which the whole matter can be discussed more intelligently. The geological relations, mode of occurrence and origin of these ores is a very large subject, and cannot be adequately treated at a single session of this meeting. I may, however, state in this connection that even Mr. Hixon's clear and simple treatment of this complicated question has failed to convince me that I am in the slightest degree in error in my explanation of the present position and dimensions of these ore bodies. As described in my report, there are several varieties of greenstones differing considerably in age, which outcrop in the Sudbury district. Mr. Hixon's failure to discriminate between these perfectly distinct types, has rather added to the confusion, while at the same time, his non-recognition of the close genetic relationship existing between the peculiar quartz-hypersthene-gabbro or norite along the borders of which all of the ore bodies have been developed, has added still further to the intricacies of the subject. Dr. Dickson, who has given his support to the hypothesis of the secondary origin of these ore bodies, will at this same meeting, give a description of certain other sulphides which are in his opinion, analogous, and whose mode of occurrence as studied in thin section under the microscope, bespeak their derivation as a direct result of secondary action. After all, however, there may be no very great divergence in our views, for while I favour the doctrine of magmatic differentiation, or the formation of the ore bodies during the earlier stages in the cooling of the magma, Dr. Dickson, as I understand him, regards them as the result of certain "after actions" not necessarily connected with any eruptive mass now in evidence in the district.

DR. DICKSON.—I have taken up the subject in a somewhat different way from Mr. Hixon and while I was not able to follow all his

remarks at the short notice, still the final conclusions are to a certain extent similar. I intend to lay more stress on the secondary origin of these ores rather than to their primary magmatic segregation. As Dr. Barlow has just said it is perhaps more a matter of degree than anything else, and while I consider that the Geological Survey has, perhaps gone to one extreme, I might have gone, perhaps to the other and ultimately it may be that we will find the solution of this problem in a somewhat intermediate stage.

As a matter of fact in a few minutes talk like this it is absolutely impossible to lay emphasis on all the points I have gone into, and on which I base these conclusions. I do not deny in the least that these rocks, such as are found in Sudbury and other similar deposits, may not have contained pyrrhotite, for it is a generally acknowledged fact that basic rocks of this type do contain pyrrhotite, as a primary constituent. My point is that the main concentration as brought out by the microscopic investigation of these ores has not been by magmatic segregation. It has been brought out by means of my investigation under the microscope that the only way we can explain these relations of the ore minerals and rock minerals is that the ore has been introduced later. In many places the replacement can be seen quite clearly, especially in the hornblende and pyroxene, which changes into hornblende. As soon as they begin to get fibrous, then you will see the little veinlets of chalcopyrite and pyrrhotite beginning to work themselves along cleavages of hornblende and in some cases this replacement has gone on so delicately that the mineral has retained its original form. For instance in figure 5* that space just near the centre has been originally a piece of hornblende, very fibrous, and you can see the light parts, where there are still some fragments of hornblende left; the dark part is on the pyrrhotite in this case, but the original hornblende can be seen all through the pyrrhotite and replacement has gone on so delicately that it has preserved very well the original structure of the mineral. Of course, the nature of the sulphide very often prevents this, and you cannot say, conclusively in most cases, that it does preserve the original form of the mineral, but this replacement in different parts of a section can be traced in almost all its stages, from the comparatively fresh pyroxene or horn-

See page 247.

blende fragments to a fragment partly or wholly replaced by ore.

Mr. HIXON.—You said you did not see how a piece of granite could be carried up by the solution. It is on record that millions of tons have been blown out. It would not take much to carry up a piece of granite the size of your fist.

Dr. DICKSON.—If you are going to advance the hypothesis that the stuff was blown out like a geyser that is a new theory.

Mr. HIXON.—That is exactly my position.

Mr. HOPPER.—As I understand Dr. Dickson, his main study was of the St. Stephen deposits and he is not basing his correlation simply on the microscopic study between Sudbury and St. Stephen. I mean the relation as to the origin, not merely upon correlation from microscopic studies, but also from studies in the field.

Dr. DICKSON.—As my basis for the field geology, I have taken the work done by the Canadian Geological Survey. I did not mention that in going over it rapidly.

Mr. HOPPER.—Might it not be possible, or more than possible, quite probable in fact, that you would find deposits of similar ores, which had originated in different ways at such long distance apart as St. Stephen and somewhere else?

Dr. DICKSON.—That might be. Each deposit, of course, would have to be studied separately, I grant that, but I simply carried out the same method of investigation that I used in the Sudbury district, taking the ore as it was mined and examining then the relations of the ore to the rock minerals.

Dr. BARLOW.—The older greenstones and schist in the immediate neighbourhood of the larger ore bodies are often penetrated by strings and patches of the sulphide material, this phenomenon being in evidence both on a large scale, and in the section under the microscope. These large or small inclusions of the sulphide, may be regarded as intrusive in their nature, the invading material usually disposing itself into the various fissures and joint planes as well as along the lines of cleavage of the component minerals, as the direction of least resistance.

Dr. DICKSON.—I might say in Sudbury, where I spent some time collecting specimens of the various deposits, the study included both classes of ore, some in which norite was plainly to be seen, and where the pyroxene had been largely altered to hornblende.

Mr. WALKER.—Have you anything like that in St. Stephen?

Dr. DICKSON.—No.

Mr. WALKER.—You could not say what the origin of the rocks was then?

Dr. DICKSON.—They have all been subject to metamorphism there. I did not find any norite in St. Stephen. I did not hear of any being found there and I do not know that the district has been studied in detail petrographically.

Mr. HOPPER.—It might be that St. Stephen represented a different variety altogether in its origin from the Sudbury one. There is evidence on the other hand that the field relations as studied, have modified the microscopic evidence in regard to Sudbury, and it may appear so when further studies are made. You say it would take long study and a great deal of work to really get evidence on this point, and we know that with a large staff and a great many years' work it has not been done yet.

Dr. DICKSON.—Of course my views are open to correction at any time, with further study, and that has simply been the object of my investigation to get at the true nature of these ore bodies, as well as possible; and if at any further time our investigation shows that one side or the other should be considered more than the other, that is all I am looking for. I have no personal views as to whether these things should be considered one way or the other. What I want to get at is the truth of the matter, if possible, and my views are open to correction, and I would like to have the matter threshed out so we will be enabled to get at some conclusion; but I am somewhat in the same position as Dr. Barlow—until I can be shown I am wrong, I am not going to change my ideas.

Dr. BARLOW.—As Dr. Dickson has based his conclusions, mainly if not altogether, on the evidence of the relations of these sulphides to the component rock minerals as exhibited under the microscope, may I ask him how can he account for the presence of practically unaltered hypersthene in portions of the nickel-bearing eruptive, which contain an appreciable amount both of the pyrrhotite and chalcopyrite. Hypersthene and the associated diallage, are extremely susceptible to alteration, the former mineral especially, breaking down into bastite or some closely related decomposition product, in the presence of even a very slight degree of

pneumatolytic or vein action. Some of the rock specimens from the Sudbury district in my possession, contain comparatively unaltered hypersthene in association with from 8-10 per cent. of the sulphides, the latter giving every evidence of being a primary mineral. Neither the rock nor its component minerals have suffered appreciably through alteration or deformation. At the same time I may mention the noteworthy fact as bearing directly on the point at issue, that unaltered types of the nickel-bearing eruptive can be collected in the immediate vicinity of all the working mines. These are facts which at once confronted me in the microscopic study of these and which have never been satisfactorily explained by those who advocated the secondary nature of these ore bodies. It is, however, from the study of the larger field relations of the associated rock masses, that the doctrine of magmatic differentiation finds its strongest support.

Dr. DICKSON.—I do not altogether disbelieve in a certain primary segregation, but my idea has been that all the ore deposits as we find them to-day are of a secondary nature, very largely by re-action between the rock minerals and the sulphides carried in solution. I do not see how it is possible to explain the relations of the rock minerals to these sulphides in any other way, especially when you find that the more altered the rock and the more it is changed to this hornblende, the greater the amount of re-placement which has gone on.

Dr. BARLOW.—I have two samples here of the nickel-bearing eruptive which are practically unaltered and which as you may see contain from 5 to 10 per cent. of pyrrhotite.

Dr. DICKSON.—These are all mineralized, which would more or less show, to bear out my contention, that the more altered the rock is, the greater has been the replacement. In those you give, the replacement has been practically nothing.

Dr. WALKER.—It seems to me that Dr. Dickson in treating of these St. Stephen's rocks has been rather side-tracked on account of his insisting that they are analogous to the Sudbury rocks. At St. Stephen there has been no field work, and Dr. Dickson has worked on rocks that are quite altered, so that at best, they can only be compared with the Sudbury ores that have suffered alteration. I don't see how you are to insist that the pyrrhotite is secondary. It does not solve the question. The positive evidence is, in fact,

that we have unaltered specimens in which the pyroxene and the pyrrhotite are side by side and are both primary.

Dr. BARLOW.—All the earlier petrographical work done in connection with these rocks was undertaken by geologists who had little or no acquaintance with the field relations. The hand specimens on which these studies were conducted, were collected rather indifferently and without due appreciation or discrimination. Unfortunately, too, all of these specimens, with one noticeable exception, were apparently of gabbroic or diabasic type in various stages of decomposition. This known specimen exception was collected by Dr. Bell from the vicinity of the Blezard mine, and was sent to the late Prof. G. H. Williams, of John Hopkins University, Baltimore, along with others for purposes of identification and description. The field relations, however, had not been closely studied, and the exposure from which it had been collected, was regarded as belonging to a dyke. Prof. Williams, however, remarked that it was a rock of unusual interest, and referred to it as a quartz-hypersthene-gabbro. It was some years after that the late Baron von Foullon, of the Geological Survey of Austria and Dr. Walker, gave accurate detailed descriptions of the nickel-bearing eruptive.

Dr. DICKSON.—Of course, I don't pretend to have made any investigations of the field relations in St. Stephen. The general geology of the district cannot be attempted by one man. It is the work of the Geological Survey, so that my information as to the field relations in St. Stephen, has been drawn from the reports of the Geological Survey, and while Dr. Walker insists, we must base our conclusions entirely on the fresh specimens. I do not agree with that myself.

I think we must view the whole field and take these specimens which are richly impregnated with ore, where the ore will go from 25 to 75 per cent. probably.

Dr. WALKER.—What I insist on is that these fresh ones should not be forgotten.

Dr. DICKSON.—Perhaps I have not emphasized it as much as I might have done, though in the Sudbury ores that I examined, which show norite, and so on, specimens contain hypersthene, I found the same relations with ore minerals and rock minerals. Of course, as a rule, these fresher rocks do not contain nearly the

proportion of sulphide that the more altered ones do, and I suppose it can be argued both ways that it has been because these others have been subjected to more alteration; that is the replacement has taken place in these other specimens to a larger extent.

Dr. ADAMS.—The only difficulty I have in this matter, I find there are other rocks which contain heavy material, such as iron ores. These iron ores in some unaccountable way, instead of falling to the bottom, remain higher up.

Mr. HIXON.—I take it iron ore is a result of surface decomposition. The solutions have gone off into peat bogs and been precipitated, and subsequently embedded and by metamorphism, have been converted into hard ores. Exactly the same conditions prevail in the iron ore deposits as prevail in coal, and iron ores pass gradually from bog ore to magnetite. Prof. Van Hise will tell you that every one of the Lake Superior deposits is a result of decomposition and precipitation in connection with the organic matter. In such cases the deposits are bedded, and you have deposits of hemetite and magnetite produced from bog ore. That is why iron ore does not have a flat surface. I believe just that far in magmatic segregation : that there is magmatic segregation to the extent of the separation of the magma into individual crystals, but no further.

Dr. BARLOW.—Mr. Hixon has, at least, admitted that magmatic differentiation finds some support in the relations of the component minerals of certain igneous rock masses. If then the intrusive nature of the immense area of norite is admitted, the formation of these ore bodies with their present position and dimensions, as the direct product of its differentiation, is entirely conceivable.

Mr. HIXON.—You can see that plainly enough in the separation of granite into quartz, feldspar and mica.

Dr. BARLOW.—The geology of the area in the immediate vicinity of the Victoria mines is very complicated and most of the rocks have undergone the extreme of alteration and deformation. It would seem that the evidences of secondary action is much more pronounced in the case of this mine than any of the others to which we devoted our attention and study; but even these ore bodies have clearly separated along the margin of an eruptive which has been defined by Dr. Coleman. When work was re-

sumed in the Sudbury district, after many years absence, our first attention was directed to ascertaining the continuity or otherwise of the Victoria mines eruptive with that along the borders of which the Creighton, North Star and other deposits are situated. This continuity established, a reconnaissance was made of the whole of what was then known as the main or southern nickel range, and the nickel-bearing eruptive was traced without a break from Drury to Falconbridge township. It has now been definitely proved by later work undertaken by Dr. Coleman for the Ontario Bureau of Mines, that the eruptive, which has been described as belonging to three distinct ranges, is really one huge ellipsoidal mass, probably representing the edges of a huge, platter shaped laccolite. Geologists have always inclined to the belief that these deposits would continue to great depths, my own opinion being that mining can be carried on as deep as will be found profitable. This continuity in depth is especially true of the marginal type of deposits.

Before resuming my chair I would like to point out that Dr. Dickson's unbelief in the direct magmatic origin of these ores has, so far, led him astray, that he even raises the question as to the ultimate source of the sulphide material, when the parent eruptive is always in immediate association. The simple doctrine of the direct igneous origin of these ore bodies and their intimate relationship in this respect with the large mass of hypersthene-gabbro or norite, served an excellent practical purpose in directing and controlling all the earlier prospecting work. It has survived all attacks which have been directed against it as the only adequate explanation of the origin of these world-famous Sudbury nickel deposits.

Dr. ADAMS.—There does not after all, seem to be so great a divergence of opinion between the members of the Institute on this subject as would appear. All believe that there has been magmatic differentiation, one side, however, thinks that there has been a good deal of differentiation while the other side thinks there has been a pretty good deal.

The CHAIRMAN.—I will just say that I concur with what Dr. Adams has said as far as I am concerned. It seems to me that the discussions and all the evidence so far brought on this subject prove that both theories are correct.

GENETIC RELATIONS OF NICKEL-COPPER ORES,

WITH SPECIAL REFERENCE TO THE DEPOSITS AT ST. STEPHEN, N.B., AND SOHLAND, GERMANY.

By Charles W. Dickson, M.A., Ph. D., School of Mining. Kingston.

Introduction.

Before discussing the ore-deposits of St. Stephen, and Sohland in particular, it might be well to briefly review the geological relations of nickel ores, in general. Economically we have to deal with the following classes of Deposits.

(1) Compounds with arsenic, (more rarely antimony,) or with arsenic and sulphur.

(2) Sulphur compounds, including pyrrhotites, and pyrite.

(3) Oxidised compounds, mostly silicates related to serpentine.

Nickel is universally recognised as an associate of pyrrhotite. But it is also well known that in different pyrrhotites the percentage of nickel varies widely. And on this basis, pyrrhotites may be subdivided into two main classes, and this classification is intimately connected with the geological relations of the sulphides.

(1) Pyrrhotite occurs with more or less chalcopyrite and pyrite, as lenses in *acidic gneisses and schists*. These lenticular masses nearly always conform to the foliation of the gneisses, and are often repeated and connected by leaner zones, after the nature of the so-called "fahlbands". Such deposits are of world wide distribution, but the pyrrhotite is *always low in*

nickel, seldom containing more than 0.5, and generally less than 0.25 per cent.

(2) The second class is also widely distributed, and from an economic standpoint, calls for special attention. These deposits are also lenticular in shape, but are associated with *basic igneous rocks*, usually of the gabbro type, or their metamorphic equivalents. There is always more or less chalcopyrite and pyrite present, and at times rarer minerals, and the characteristic minerals of the basic rock are always intimately mixed through the prevailing sulphides. Nickel is almost invariably present in the pyrrhotite, at times up to 10 per cent or more, but on an average, (e. g. in Sudbury), 2 to 4 per cent.

To the latter class of pyrrhotites, the St. Stephen deposits belong.

Many writers in recent years have attributed a direct igneous origin to this class of pyrrhotites. The sulphides are regarded as original rock constituents, and the theory is that they crystallized, from the cooling magma, in their present position, by a "magmatic segregation".

A thorough investigation of the Sudbury deposits has led me to the conclusion, that this theory of a direct magmatic segregation is untenable.This must, however, not be taken to imply, that the sulphides may not have been, to a large extent, original constituents of the basic magma. Also there may have been a partial concentration, during the cooling of this magma. But from the studies of the Sudbury and St. Stephen ores, there seems to be only one explanation possible, as to their present position. Namely that the deposits are largely secondary replacements along more or less crushed and faulted zones, by means of circulating solutions containing ore, which has been deposited by a metasomatic interchange, with the rock minerals; that is, that the main concentration of the ore, as seen at present, is of a secondary nature, *after the solidification of the magma*, and is not an orig.nal direct segregation from the cooling, but still molten magma.

The study of a somewhat similar deposit near Sohland,

Germany, has led Prof. Beck, and myself to a similar conclusion in this case also.

As work has been discontinued for the present at St. Stephen, it was impossible to gain access to the mines. I was however furnished with material through the kindness of Messrs. W. K. and A. D. Ganong, of St. Stephen, which has proved amply sufficient for the present investigations. On the property from which these samples were taken, two shafts have been sunk, to the depth of 125 feet, and 80 feet respectively. Further prospecting has been done with a diamond drill, and though it is difficult to get exact information, I have been informed that a body of solid ore,18 feet thick has been located.

ST. STEPHEN, N.B.

While the nickel-copper deposits of St. Stephen, have not as yet assumed the importance of producing mines, they are of more than passing interest. Aside from their possible economic value, they supply us with a great deal of information, which throws light on the genetic relations of this class of sulphide ores.

Mr. H. P. Brummel briefly sums up the geological relations of the deposits*, and Prof. L. W. Bailey gives us some further particulars in a later report. **

The Deposits.

Throughout the country north of St. Stephen, are large areas of diorite, with which are associated, more or less extensive deposits of pyrrhotite, and chalcopyrite, the former carrying nickel. The pyrrhotite masses are almost invariably capped by a gossan resulting from the oxidation of the sulphides. The rocks of the entire district consist of coarse and fine grained diabases, and diorites. They show the effects of severe metamorphism, and are often slickensided, and highly charged with sulphides in the vicinity of the ore-bodies.

* Geol. Sur. of Can., vol. V, new series, 1890-'91, p. 112 S.S.
** Geol. Sur. of Can., vol. X, new series, 1897, p. 27 M.

Attention was first drawn to these deposits after the discovery of similar ores near Sudbury, and analyses showed that the St. Stephen pyrrhotites carried a small percentage of nickel. Numbers of test pits were sunk, showing the wide distribution of the pyrrhotite, and steps were taken to determine their value. Some of the ore bodies proved quite extensive, but the percentage of nickel was low and irregular, generally averaging 0.75 to 2%. In many cases only traces were found, though some samples showed as much as 4%.

In 1897 Prof. Bailey made a careful examination of some of the more important localities, and calls attention to some of the principal features of the deposits. Compared with Sudbury, they show many features of similarity. (1) The St. Stephen beds like those of Sudbury, consist of basic intrusives, as diorite and diabase, with probably gabbro, and norite, associated with heavy beds of quartzite. (2) As at Sudbury the pyrrhotite would seem to be a normal constituent of the dioritic rock, and not an intrusion into the latter. (3) The St. Stephen rocks like those of Sudbury are referable to the Huronian system, and were probably formed under like conditions. On the other hand the average percentage of nickel in the St. Stephen ore, is much smaller than in Sudbury.

Nature of the Ore.

The St. Stephen ore consists of prevailing pyrrhotite with chalcopyrite and a very subordinate amount of pyrite. Through the ore are also small grains of magnetite. The magnetite does not however, so far as I have observed, occur in any considerable masses, but is present simply as an original residual, accessory of the enclosing rock. The pyrrhotite is nearly always finely granular and compact. At times it is nearly pure, without chalcopyrite, and having only isolated grains of silicates, as impurity. But these masses of pure ore are never extensive, and seem to be of comparatively local development. The pyrrhotite is mixed with more or less of the rock silicates, and also contains chalcopyrite. The amount of rocky inclusions varies consider-

ably, as is the rule in such deposits, and in places may equal or exceed the sulphides. The chalcopyrite seems to be irregularly distributed. It seldom occurs in considerable masses, in any degree of purity, but is often closely associated with pyrrhotite, especially where the latter is mixed with a considerable amount of rock.

The relation of the chalcopyrite to the pyrrhotite is very interesting and significant. A number of polished sections of the mixed ore were made, and in all of them the same phenomena were noted. The ore-rock is traversed in various directions by small parting planes and fracture zones. These are apparently the result of a dynamic movement which shattered the rock to a considerable extent. The parting planes do not seem to be confined to any one part of the rock, and traverse both pyrrhotite and rock proper. But they are *most apparent along certain lines where large phenocrysts of feldspar are abundant.* Also in connection with the feldspar, the development of chalcopyrite is most pronounced. The chalcopyrite extends along these lines of weakness in the form of veins, often terminated abruptly against the side of a comparatively fresh feldspar crystal, and ramifying irregularly, between the neighboring minerals, in a network of fine veinlets. In cases where a feldspar crystal has been shattered, and more or less decomposed, the chalcopyrite can be seen, penetrating it in all directions, along the cleavages and partings, in the form of delicate apophyses.

The conclusions to be drawn from these relations are very significant. That the chalcopyrite is a *later introduction* is shown conclusively, and this is an important fact in considering the paragenesis of the ore. It is evident that a dynamic movement has taken place *after* the formation of the principal body of the ore, namely the pyrrhotite. And along these parting planes, due to the dynamic effect, solutions bearing the copper sulphide, have circulated, with the foregoing result.

The conclusions are important in helping to explain certain phenomena of other deposits. Prof. Beck has come to a very similar conclusion with reference to the Sohland deposits, where

chalcopyrite is often found along planes of weakness and shear planes.

Already for Sudbury a similar idea was advanced, but here the relations are masked to a large extent by the massive nature of the ore. But with the additional evidence offered by Sohland and St. Stephen, it grows almost to a certainty, that the relations of the chalcopyrite to the pyrrhotite can be explained in the same way for Sudbury.*

Further proofs that the ore-bearing rocks have been involved in a process of dynamic metamorphism are not wanting. The rock has been more or less shattered and brecciated, and numerous cracks resembling faulting planes are present. The minerals in the neighborhood of these seams are often completely granulated and show a marked undulatory extinction. These relations are brought out still more clearly by the microscopical examination. The movement does not seem to have been on an extensive scale however, and has resulted in a brecciation of the minerals themselves, rather than of the rock as a whole. The force has no doubt acted while the rocks, now exposed, were under a considerable load, and the minerals have readjusted themselves, in a somewhat plastic condition, so that their continuity is as a rule preserved. This resulted in the formation of lines of weakness in certain directions, and a somewhat gneissoid structure of the rock, accompanied by a granulation of the minerals.

Besides this, other rocks in the immediate vicinity, show very definite results of movement, which has developed a slickensided structure, along the planes of which the rock parts easily.

The ore-rock itself exhibits a number of minor varieties. That most intimately associated with the ore, is a rather coarse grained variety of gabbro, shading to diabase. It is characterized by the presence of rather large feldspar individuals, often drawn out and compressed. The feldspar as well as the other minerals are in an advanced stage of alteration, especially where ore is developed.

Another variety, only slightly impregnated with ore, is

* See page 59 reprint "The Ore Deposits of Sudbury, Ontario," Trans. Am. Inst. of Min. Eng., 1903.

much finer grained and fresher. In appearance the rocks resemble gabbro, and will be more minutely described microscopically.

Microscopical Structure of the Ore.

The method of examination employed is practically similar to that used for the Sudbury deposits. The study of the microscopical relations of the ore and ore-bearing rocks, affords the surest means of determining the true nature and origin of this class of ore-bodies. Taken in connection with the evidence afforded by the megascopic relations, the results have proven most successful, in this case, as well as for Sudbury, in solving the problem of the origin of the deposits.

A large number of thin sections have been examined, including pure ore, and ore associated with varying amounts of rock, so that the results can be taken as representative of the entire deposit.

(1) Specimens of a medium grained, holocrystalline, hypidiomorphic granular rock, carrying a small amount of ore.

The rock is very compact and even grained, of a prevailing dark grey color, with lighter spots of feldspar, and often shows the slickensided structure mentioned above.

From the general mineralogical composition, the rock might be considered as an olivine-free gabbro. But from the prevalence of the ophitic structure, it must be classed as a transition form between a gabbro proper and a diabase. The basic nature of the feldspar however, as well as the nature of the inclusions, and the alteration products, belong more typically to a gabbro, than to a diabase.

Under the microscope the rock is seen to be made up largely of plagioclase feldspar, pyroxene, hornblende, and chlorite. Besides these minerals, there are small amounts of brown mica, apatite, quartz, magnetite, and secondary sulphides in varying amount.

The *feldspar* is as a rule fairly fresh, and nearly always builds sharply bounded crystals, about 2 to 4 times as long as broad. With reference to the pyroxene they are idiomorphic. The crystallization of the feldspar has apparently begun before that of

the pyroxene, and extended through it, so that the feldspars appear to lie in a cement of pyroxene. (See Fig. 6.)

Twinning according to the albite law is universal, an pat times is combined with a carlsbad twinning. Measurements of the extinction angle range up to 32 and 34 deg., showing that the feldspar belongs to the basic end of the group, that is, bytownite or anorthite. In the feldspar crystals themselves, are numerous, zonally arranged needles, of a highly refracting mineral, whose exact nature could not be determined, but which is probably rutile. There are also inclusions of a secondary

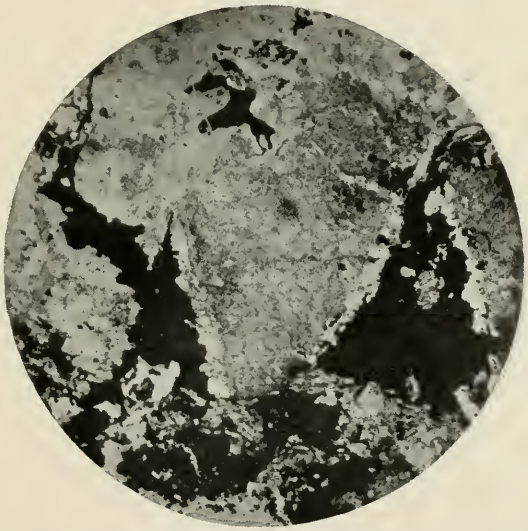


Fig. 1.—Ore rock, showing pyrrhotite replacing feldspar, and hornblende along shearing planes, which can be traced through the section. The rock minerals in the vicinity of the ore are largely altered to aggregates of decomposed feldspar, fibrous, green hornblende and chlorite. There are a few grains of colorless epidote, and a small amount of fresh, regenerated feldspar.—Magnified about 70 diameters.

nature, where alteration has begun. These consist of small centers, of highly refracting particles, of a saussuritic nature. The feldspar resists alteration much better than the other minerals.

The prevailing pyroxene is most closely related to diallage, but is peculiar in some respects. A few grains of other pyroxenes, resembling diopside, and an orthorhombic variety, were also noticed, but the amount is very subordinate. The diallage as

stated is without crystal boundaries, and forms a cement for the feldspar. The color is light brown, often with a tinge of violet, (indicating titanium). Pleochroism is very faint, and only observable as changes of shade. Besides the ordinary cleavages, which are well developed, the pyroxene is characterized, in that it possesses the peculiarity of a decided *fibrous structure parallel to the base.* The maximum extinction angle is high, corresponding to diallage, and reaches 39 to 40 deg. Regular intergrowths with diopside as well as with brown hornblende, are frequently noticed.

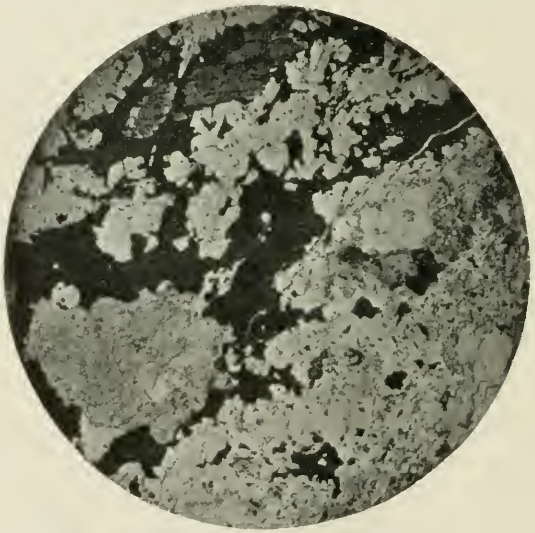


Fig. 2.—Ore-rock with considerable calcite, showing the etched borders of the epidote and hornblende, and ore along the cleavages and between the grains. A fragment of brown hornblende, partly fresh and partly bleached, and altered, is cut entirely in two by the ore, which is also seen along its cleavage planes.—Magnified about 70 diameters.

The pyroxene is always in a more or less advanced stage of alteration, which makes its exact determination at times difficult. In most cases it is filled with fine dust-like inclusions, of both a primary and secondary nature. The latter are highly polarizing and consist of calcite and epidote, with more or less of a talcose mineral. Again it is often pierced with numerous needles of a secondary green hornblende, or chlorite. In a further stage, a green fibrous hornblende, resembling actinolite, results,

commencing from the periphery and along cleavages. As the alteration proceeds still further, chlorite, (var. pennine,) results, which may color the surrounding minerals green for a considerable distance.

Besides the secondary green hornblende mentioned, a brown variety is quite abundant. In some cases it is undoubtedly primary, but may in part be derived from the diallage. The advanced decomposition of the dark silicates, often makes it difficult to decide which is primary and which is not. This hornblende is usually of a dark color, with a violet shade, when fresh, and the

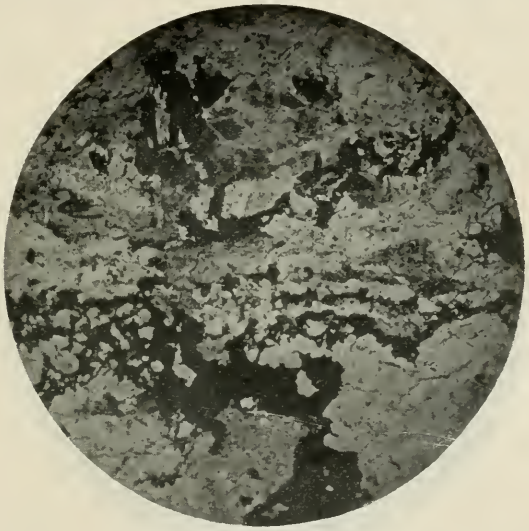


Fig. 3.—Ore-rock, with part of an irregular veinlet of sulphides, along a line of weakness, where the rock is much crushed and decomposed. Residues of epidote, pyroxene, etc., can be seen entirely surrounded by ore. The epidote is finely granulated, and shows the effects of a severe dynamic strain. It is also filled with decomposition products, and associated with calcite, while chlorite is also abundant. Small amounts of altered hornblende and diallage also remain, partly replaced by ore.—Magnified about 65 diameters.

pleochroism is strong. A greenish color or bleaching, usually results as the first stage of chemical alteration, and it gradually passes to fibrous aggregates of green secondary hornblende, and finally to chlorite.

The small amount of quartz is apparently primary. It is mostly clear and fresh, but also contains small needle-like inclusions, and infiltrated hornblende. The amounts of apatite and

brown mica are very subordinate, and the latter is evidently secondary. Magnetite as a primary accessory constituent, is in quite large amount, and in some cases the sulphides are important.

Relation of Sulphides.

In contrast to the primary magnetite, the relation of the sulphides to the rock minerals is striking. Besides the primary magnetite, however, is a small amount, in fine-dust like particles, which results from the alteration of pyroxene and hornblende. The *primary* magnetite is always in the form of more or less

Fig. 4.—Ore-rock, showing part of a veinlet of chalcopyrite and pyrrhotite, which extends across the section along a line of shearing. The epidote and pyroxene are granulated and strained by pressure, showing undulatory extinction and a curved cleavage. The sulphides replace the pyroxene and epidote in a typical manner, etching the borders of the grains and extending along the cleavage planes.—Magnified about 70 diameters.

rounded grains, enclosed in the dark silicates and sulphides, with unaltered contours.

The ore which is almost exclusively pyrrhotite, is largely confined to the neighborhood of the dark silicates. It is possible that it has in part, been formed in place, by sulphur-bearing waters reacting on the iron, resulting from the alteration of the silicates. But whether the sulphides originated in this way, or

were introduced from external sources, they are certainly secondary.

Where the hornblende and pyroxene are still fresh and compact, the sulphides form a border around them, sharply defined by the edge of the mineral. But as the rock minerals become more altered and fibrous, the change proceeds further. At first, fine threads of sulphides insinuate themselves, between the fibres and along the cleavages, and may finally replace the whole silicate fragment. This often results in a more or less complete pseudomorph, but the change has gone on so delicately, that the

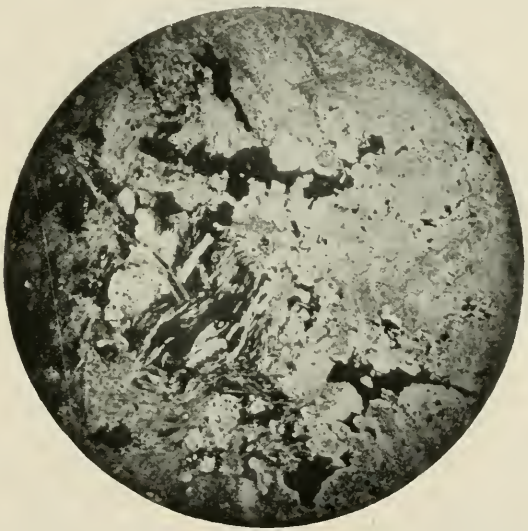


Fig. 5.—Ore-rock, showing decomposed feldspar, with secondary hornblende and chlorite. About the center can be seen an area of secondary, greenish, fibrous hornblende, which is largely replaced by ore, but in such a manner that the sulphides retain the original ibrous structure of the hornblende.—Magnified about 50 diameters.

sulphides preserve the *fibrous structure* of the replaced mineral. This change of course, is very often incomplete, but the principle is always the same, and the *greatest development of sulphides is always found, where the alteration of the rock minerals* is most prominent.

(2) Rock strongly impregnated with ore, taken from the shaft, at a depth of 30 feet.

The rock itself is a diabase gabbro, with a hypidiomorphic-

granular structure; in places rather coarse grained, and with prominent feldspar crystals.

A somewhat gneissoid structure, and slickensided surfaces have been developed by dynamic stresses.

The principal constituents are: feldspar, epidote, pyroxene, hornblende, and chlorite, with apatite, magnetite, calcite, etc., as accessories.

The feldspar is a basic plagioclase, approaching labradorite, or bytownite, and when not too much altered, shows a typical albite twinning. As a rule the feldspar is in an advanced stage of

Fig. 6.—Comparatively fresh ore-rock, showing typical ophitic structure, with feldspar in excess, in a groundmass of diallage. Crossed nicols.—Magnified about 50 diameters.

decomposition, and the twinning structure may be entirely obliterated. It builds irregular grains and aggregates, but often presents good crystal outlines, in a ground-mass of pyroxene or hornblende, giving the section somewhat the appearance of a diabase. Most of the feldspar has passed to indistinct aggregates of highly polarizing secondary products, consisting of calcite, sericite, or saussurite, and colored greenish by migrated hornblende and chlorite. Fig. 1 shows such an altered feldspar individual. Around the edge of the altered grains can be seen a rim of clear "*regenerated*" feldspar, in optical continuation with the old.

One of the most prominent minerals is a clear variety of epidote, characterized by the fact that the plane of the optic axes is at right angles to the cleavage. It is always in the form of irregular grains, sometimes quite large, with no approach to crystal form. Seen in ordinary light, the grains appear as one individual (See Figs. 2 and 4). But between crossed nicols, the mineral has a marked undulatory extinction, and the mass breaks up into a mosaic of small and irregularly oriented grains, showing the effect of severe crushing. The epidote is usually quite fresh, but where most crushed and granulated, it is intergrown with secondary hornblende and chlorite. (Fig. 3). The epidote stands in very close relation to the sulphides, and the origin of both is no doubt closely connected with the same metamorphic processes.

The chief pyroxene is diallage. It is usually in rather irregular plates, without crystal outline, and shows a more or less fibrous cleavage. A regular intergrowth with hornblende is common. (See Fig. 4). The diallage is in various stages of alteration first changing to secondary hornblende, and then to the variety of chlorite, pennine. The alteration takes place along the cleavages, and from various centres. The brown color is bleached, the double refraction becomes weaker, and a fibrous aggregate of hornblende and chlorite results.

The next most important mineral is the brown hornblende. This is evidently primary, and shows the usual pleochroism and cleavage. In part it is quite fresh, but more often it is altered to secondary actinolitic and tremolitic hornblende, and finally to chlorite. (Hornblende, in various stages of alteration are seen in Figs. 1 and 2.) The secondary green hornblende, which is very abundant, is derived from both the pyroxene, and hornblende. It is partly in the form of irregular grains but more frequently in tufts, and fibrous masses, irregularly oriented. A further alteration ends in a confused mass of hornblende fibres and pennine, mixed with indefinite secondary products.

Calcite as a secondary product is often quite prominent, especially in connection with the ore and epidote. (Fig. 2). The usual accessory minerals of gabbro occur in small quantities, but are not important.

Relations of the Ore.

The relation of the sulphides to the rock minerals is very

characteristic. In all the sections belonging to this type of rock described above, they are identical, and fully demonstrate the secondary nature of the ore.

That the rock has been subjected to the forces of dynamic metamorphism, is borne out by the microscopical examination. The constituent minerals are brecciated and deformed, and the rock is crossed by many small breaks and cracks, both of a megascopic and microscopic nature. Along these lines of weakness, the effects of pressure and strain are most apparent. The granulation and alteration of the minerals is here most pronounced, and ore is always present in the form of veinlets, following the direction of the fracture planes. Under these circumstances, calcite and epidote are usually abundant, and from this it may be inferred that the ore has been formed in part later, by means of circulating waters, as well as during the actual metamorphism. Such veinlets are shown in Figs. 2 and 3; very typically in the latter. It is not likely that actual open fissures resulted, or ever existed. The effect of the dynamic stresses was to prepare a line of least resistance, along which the ore-bearing solutions found their way, and left the minerals in such a condition that they could be easily replaced. Fig. 3 shows this distinctly. The ore has replaced the brecciated minerals along such a fracture plane, and left small residual grains unreplaced and *surrounded by ore*. The veinlets often cross the entire section, but are never uniform. They expand and contract, and send out ramifications among the surrounding minerals, in a very typical way, and replace them to a considable extent.

In connection with the epidote also, the sulphides are prominent. They form an irregular network, between the grains, which make up the larger aggregates. They force their way between the grains, etching them, and finally isolating them from the main mass. They find their way along cleavage cracks, and planes of weakness, so that the grains finally appear in a matrix of sulphides, which holds them together. (See Figs. 2 and 4).

Replacement has gone on most actively in connection with the epidote, pyroxenes and hornblende, and their alteration products. But where the feldspar has been crushed and broken, it is also attacked and is very frequently seamed with sulphides, though to a smaller extent than the bisilicates.

The rock contains a considerable amount of magnetite, of a primary nature, but as before, it presents a strong contrast to the sulphides. It is in the form of rounded or elliptical grains, and never has the numerous vein-like ramifications, which characterize the latter.

(3). A third variety of ore-rock is found in the shaft. It belongs to the gabbro type, but is much lighter in color than the others, owing to the prominence of large individuals of a whitish feldspar. Taken as a whole, the rock is very similar to the last, but with a number of interesting variations. Alteration has reached an advanced stage; the feldspars are composed of turbid masses of secondary products, and both hornblende and pyroxene are almost completely changed to secondary hornblende and chlorite. The epidote which was so prominent in the other variety, is here lacking, and diallage cannot be identified with certainty. It is evident that a great deal of the secondary hornblende was derived from original pyroxene, but this could not be directly proved.

The most interesting mineral is the feldspar. Along its cleavages, and bordering the altered mass, is a clear, fresh, glassy feldspar, which is much more acid in composition than the main mass. That it is not a simple zonal arrangement, appears from the fact, that the fresh feldspar is found along the breaks as well as around the edges. We must be therefore be dealing with a secondary feldspar, which has been formed during or after the metamorphism. This "regenerated" feldspar, as it may be called, is a regular growth through and around the altered variety, and in optical continuation with it, but of a much more acid nature. The new feldspar is clear fresh and glassy, and contains no inclusions. This regenaration of feldspar is exceedingly interesting, and for a rock of this kind rare. That quartz grains, and at times feldspar, in sandstones and related rocks, are enlarged by secondary processes, is quite well known. That it should occur in other rocks, especially those subjected to the influence of dynamic metamorphism, is therefore not strange. At the same time it is so uncommon, as to deserve special mention. The other rock minerals, consisting now largely of secondary hornblende, and chlorite, (pennine), occupy the spaces between the large feldspar crystals.

The sulphides as usual are most intimately associated with the dark silicates, which they replace in a characteristic way.

The feldspars, although strongly altered, have not been extensively replaced by ore, except where they have been crushed and broken, and then the ore is found filling the planes of fracture.

The replacement of hornblende and chlorite by ore, is typically developed, and a number of almost complete pseudomorphs can be seen. (Fig. 5.)

(4). Specimens consisting almost exclusively of ore, do not show anything new. The rock residue consists largely of feldspar, with a small amount of green hornblende, and chlorite. The minerals are all strongly decomposed, and are penetrated by threads of ore along all lines of weakness, and in some cases are almost wholly replaced.

CONCLUSION

From the results given above it is possible to draw a number of conclusions, with certainty. Briefly these are as follows:—

(1). The deposits are *not* the result of a direct magmatic segregation from an original magma.

(2). The ores are largely of a secondary nature, deposited from circulating solutions, by a metasomatic replacement of the rock minerals.

(3). The relations of the rock minerals, can only be explained by such a replacement.

(4). Where the effects of metamorphism, in the crushing and alteration of the rock, are most apparent, the largest quantity of ore is developed.

(5). The ore has been introduced into the rock, *after* its complete differentiation and solidification.

(6). The ore first replaces the rock along planes of brecciation and least resistance, and finally extends, till it has replaced considerable masses of the rock.

(7). The ore is most prominently associated with secondary non-metallic minerals, namely hornblende and chlorite.

(8). The different relations of the magnetite and sulphides, to the rock minerals, gives additional proof that the latter are secondary.

(9). Pyrrhotite at first, probably formed the larger proportion of the ore, and chalcopyrite has been introduced still later.

(10). A comparison of this deposit with those of Sudbury and Sohland, show that the three are practically alike.

The ore-bearing rocks are of the same type, with only minor differences of local development. The underlying principles of the ore-formation are essentially similar. Whether the important concentration of the ore, took place during or after, the period of metamorphism, which crushed and sheared the rock, is not clear. It is very probable however, that the metamorphism had a more or less direct effect, in stimulating the circulation of the ore-bearing solutions, as well as rendering the rock permeable to these solutions. The ultimate source of the metals themselves is still problematical. As in the case of Sudbury, the associated basic rocks, can hardly be looked upon as capable of furnishing the necessary amount of ore, by a process of "lateral secretion". The only alternative is therefore, to ascribe a more distant source to the metals, which have received their *first* important concentration by means of *ascending* waters.

Considering our comparative ignorance of the laws governing the circulation of deep underground waters, a discussion of the actual processes, which resulted in the formation of the ore-body as it is to-day, would be purely theoretical.

As the object of this investigation has been to inquire into the *facts*, as presented by the actual occurrence and relations of the ore, and not to go into theoretical details, such a discussion will not be attempted.

The Pyrrhotite Nickel Deposits of Sohland, Germany.

The geology of the interesting nickel deposits near Sohland, Saxony, discovered in 1900, has been described by Prof. Beck, in a recent valuable paper.*

Geology of the Ore Bodies.

The country rock of Sohland is the so-called Lausitzer granite,

* "Die Nickelerzlagerstatte von Sohland a.d. Spree, und ihre Gesteine" Zeit. der Deutsch. geol. Gesell., 1903.

Other literature on Sohland.

Beck, R. Lehre von den Erzlagerstätten. I Ed. 1900, p. 47; II Ed 1903. p. 46. .

Beck, R. "Ueber eine neue Nickelerzlagerstätte in Sachsen". Zeit. fur prakt. Geol. Feb. 1902, pp. 379-381.

Beyer, O. "Die erste Erzlagerstatte der Oberlausitz." Wissensch. Beil. der Leipziger Zeit. Feb. 13, 1902.

which is cut by numerous diabase dykes, and often shows the effects of metamorphism. Where the ore was discovered, the granite is fine grained; further east a middle grained variety is predominant. The ores are closely associated with diabase dykes, called "proterobase", striking in a general W.N.W. direction. The main dyke is about 30 to 60 feet wide, and has been traced for more than half a mile. Ore has been found in a number of test pits, and prospecting with a magnetometer, makes it probable that the ore-bearing rock extends at least a mile in length.

The Ore-bearing Rock.

The principal ore-bearing dyke is not uniform in character. It is most largely developed as the so-called "proterobase"; in part it takes the form of a biotite-diabase. Besides these, there are small basic segregations, containing spinel, corundum, and sillimanite.

(a). Proterobase. Without going into petrographic details, the proterobase is a fine to middle grained rock, consisting chiefly of plagioclase, augite, brown hornblende, and brown mica. The chief accessory minerals are, a colorless pyroxene, magnetite, ilmenite, apatite, zircon and rutile, as well as secondary green hornblende, talc, chlorite, and serpentine.

(b). Biotite-diabase. The biotite-diabase is much finer grained, and occurs as irregular nodules within the proterobase. Its microscopic structure is typically ophitic. Brown hornblende fails, otherwise it is very similar to the proterobase, with which it is connected by gradual transitions.

(c). The basic segregations are of two kinds. One (not found in place) is characterized by countless octahedra of a green transparent spinel, and a few grains of corundum. The other variety, which is found in the ore body, is made up largely of aggregates of sillimanite, and contains large numbers of spinel and sapphire crystals.

Besides these minor varieties, the proterobase contains inclusions of quartz and granite, the latter strongly altered.

Mineralogical Composition of the Ore.

Besides the magnetite and ilmenite mentioned as original components of the rock, the Sohland ore consists of pyrrhotite,

chalcopyrite, and pyrite. The pyrrhotite is largely in excess of the others, and the mining activity is due to the nickel it contains, as the ore is too poor to work for copper alone.

The pyrrhotite is always massive, and two varieties can be distinguished. One is more or less granular and fine grained, the other more coarsely crystalline and platy. Chalcopyrite is always intimately intergrown with the pyrrhotite, especially the finer grained variety. The latter also contains many more inclusions of the proterobase, while the coarser is as a rule comparatively pure, and free from rock and copper.

Analyses of the Sohland pyrrhotite show an average of between 4 and 5 per cent nickel, for nearly pure material. But in a number of cases I obtained as much as 7 per cent. Copper is generally rather subordinate, averaging between 0,5 and 1 per cent, but at times going as high as 2 to 3 per cent. Cobalt is present in very subordinate quantities, and traces of antimony and silver have been detected.

The Ore-Body.

The ore-bed proper lies in the proterobase at the granite contact. At the bottom of the shaft sunk where the discovery was made, it has a thickness of 6 to 8 feet, which, however, sinks to a foot or less. The granite itself at the contact is slightly impregnated with ore for a few inches. The pay ore ends rather abruptly and beyond is proterobase impregnated with diminishing quantities of sulphides.

The upper part of the vein (Fundschacht) is covered to a depth of about ten feet with clay and the alteration products of the proterobase. Below this, secondary oxidised copper ores appear, (malachite, bornite, chalcocite, etc.). The rock becomes gradually fresher and more strongly impregnated with sulphides, till at a depth of about 30 feet, massive ore is met.

Relations of Ore and Rock

Examined more closely, the relations of the sulphides to one another, and to the rock minerals, present a number of interesting facts.

In the massive ore, the small amount of chalcopyrite, in part fills narrow clefts in the pyrrhotite, as though a later impregnation

along planes of fracture. A bilateral arrangement of the sulphides is also characteristic, and is well illustrated by a number of polished sections in Prof. Beck's collection.

One section shows a narrow band of chalcopyrite, running through the proterobase, which is locally altered and somewhat talcose. On either side of this band, the proterobase is impregnated with chalcopyrite for 3 or 4 inches. Then follows a parallel band of pyrrhotite, which is marked off sharply on the inner side, and fades off gradually to barren proterobase on the outer side. Other sections show similar zonal structures, giving the ore a more or less vein-like appearance. At other times the sulphides are grouped regularly around elliptical or rounded rock masses, apparently along fracture planes. The inner zone is generally chalcopyrite, and is surrounded by pyrrhotite, which passes by a gradual transition to barren rock. The same phenomena have been noted in the Sudbury ore, and they afford one of the clearest proofs of the later introduction of the ore, especially when combined with the microscopic observations.

Microscopic Structure of the Ore.

From the examination of a large number of thin sections of ore, Prof. Beck draws the following conclusions.

(1). The sulphide ores fill a space originally occupied by primary rock constituents.

(2). The sulphides are principally associated with secondary, non-metallic minerals, viz. actinolite, and chlorite.

(3). The sulphides favor places where alteration is well advanced. They occur in all varieties of the rock, but especially in the predominant proterobase.

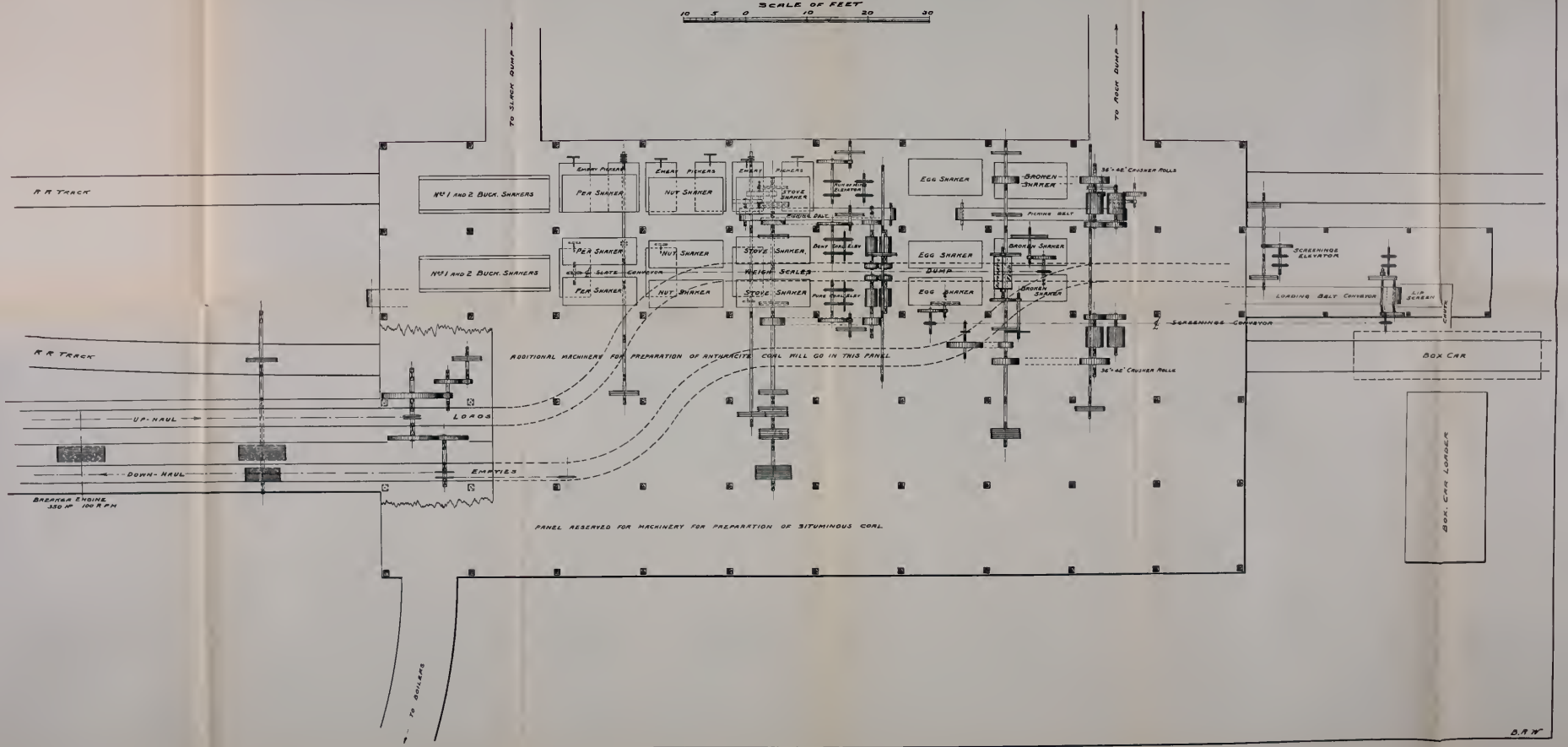
The general conclusions are supported by concrete examples, and an examination of the slides I have made, fully corroborates the observations of Prof. Beck.

Origin of the Ore.

Prof. Beck's work, as well as my own, then make a number of points clear.

(1). Except for a small proportion of sulphides, which may have been original constituents of the ore-bearing rock, the

PLAN
— OF —
THE PACIFIC COAL COMPANY'S BREAKER
BANKHEAD - ALTA.



pyrrhotite, chalcopyrite, and pyrite, have been introduced *after* the complete cooling and differentiation of the rock magma.

(2). Not only so, but a partial alteration of the silicates has taken place, resulting in the formation of actinolite, chlorite, talc, etc., *before* the formation of the ore-bodies.

(3). These relations can only have been brought about by means of solutions.

(4). The peculiar intergrowth of secondary hornblende and ore seems to indicate a previous metamorphic action. The fresher silicates are simply corroded and etched, while a part has been further altered during the action of the solutions and the contemporaneous deposition of ore.

(5). The ore-bearing solutions in all probability, were of a thermal nature, from considerable depths. They circulated along the border of the proterobase, along passages formed by cooling and shearing, and were no doubt closely connected with the latter stages of the proterobase eruption.

The ore-body itself indicates the thermal nature of the solutions, and their origin from the depths of the basic magma. If the process had been a lateral secretion of descending waters, which concentrated the nickel and copper, originally disseminated through the proterobase, it is difficult to understand why the ore is confined to the proterobase, along its contact with the granite.

Comparison with Sudbury and Other Deposits.

A short comparison of various sulphide nickel-copper deposits, indicates their essential similarity, both of geological relations, and method of origin.

(1). Regarding their origin, no example of this class of ore-bodies, which I have studied, can be referred to as a direct magmatic segregation from an original rock magma. On the other hand, all the evidence shows that the ores were introduced *after* the complete differentiation and solidification of the magma. Many facts point to the conclusion that the important concentration of the ore, took place *during* a regional metamorphism, probably connected closely with the eruption of the basic rock, and *later* by a stimulated aqueous activity, following the eruption.

(2). Considering the ore bearing rocks themselves, they are found to be essentially similar. They all belong to the gabbro

family, and while showing minor points of difference, for practical purposes they can be considered as identical.

(3). The deposits while lying well within the limits of the basic eruptive, generally occur at or near its contact with other rocks, especially granites and mica schists.

The rocks show to a greater or less extent the effects of dynamic metamorphism, accompanied by brecciation and shearing. These are perhaps more apparent in the Sudbury field than the others studied, but are never failing.

(4). The mineralogical relations are practically the same in all the deposits. Pyrrhotite containing nickel is predominant. Associated with it are varying amounts of chalcopyrite, pyrite, and magnetite, (usually very subordinate), and the rarer minerals (at times), pentlandite, sperrylite, etc.

(5). The ore frequently occurs as a cement for the brecciated rock fragments and along shear planes. This often gives to the ores a vein-like appearance or zonal structure, as is well seen in both the Sudbury and Sohland deposits.

(6). The rocks associated with the ore are strongly altered, and characterized by the presence of much secondary, green and amphobilitic hornblende, chlorite etc. The effects of metamorphism and the development of secondary hornblende are most marked near the ore-bodies, and diminish away from them. And in general the more complete the alteration of the rock, the more complete has been its replacement by sulphides.

(7). Microscopically the relations of the ore and rock emphasize the fact that the sulphides are a secondary introduction. The relations of the magnetite and ilmenite, which are for the most part primary, are in striking contrast to the sulphides. While the latter are found in positions originally occupied by primary rock constituents, the former are in the form of grains and crystals in the midst of the sulphides, and dark silicates, apparently unaltered and with their original outlines. The sulphides on the other hand, replace both the fresh and altered rock constituents, often forming more or less complete pseudomorphs. The replacement takes place between the fibres of the secondary hornblende; along the cleavages of the fresher and more compact minerals, etching them and breaking them up into granular aggre-

gates ; between crystal fragments ; and along planes or zones of shearing and parting.

The dark silicates, owing to their chemical composition, and susceptibility to metamorphic changes, are the first attacked. But as the effects of metamorphism become more pronounced, the more acidic minerals (feldspars) are partly or wholly altered, and replaced by ore.

Another interesting fact, noted especially in the Sudbury, Sohland, and Norwegian deposits, is that where the contact is along granitic or gneissoid rocks, the latter have been slightly mineralized. The change is usually accompanied by a migration of secondary hornblende into the acidic rock, and a replacement of its basic constituents by ore. The granite of the Sohland deposit is often sensibly altered and metamorphosed, both as a result of the eruption of the proterobase, and later by the ore-bearing solutions. The schistose and gneissoid contacts of many Norwegian deposits are often penetrated by ore for some distance, along cracks and planes of parting, which can only be explained as a deposition from solution.

Nickel in the Sohland Ore.

At the request of Prof. Beck, I made a number of experiments with Sohland pyrrhotite, in the endeavour to determine in what form the nickel was present. From the general similarity, both in geological relations and mineralogical composition, of the Sohland and Sudbury deposits, it was thought probable that the nickel might be in the form of a definite mineral, such as pentlandite. Both varieties of the pyrrhotite were examined, but no mineral resembling pentlandite was visible to the naked eye. Chalcopyrite in small nests and aggregates is intimately mixed through both the fine and coarse grained ore, and is very difficult to separate from the pyrrhotite.

After crushing, the ore was sized through Nos. 10, 20, 30, 40, and 80 mesh sieves. The various sizes were then magnetically separated by means of a small horse-shoe magnet. Practically none of the ore was *non-magnetic*, except the chalcopyrite, and and rock minerals, and these were rejected as well as possible. Part of the pyrrhotite however, was not so susceptible to magnetic attraction as the rest, and this was carefully examined. It was

freed from impurities as well as possible, and treated with dilute hydrochloric acid, to remove oxidation products. In appearance the grains were of a very light bronze-yellow color, but showed little trace of the characteristic parting of pentlandite. These were then picked over under a lens, and only the purest part selected. It was found however, very difficult to obtain a satisfactorily pure product, as small particles of chalcopyrite adhered very closely to some of the grains.

Both varieties of the ore were treated in this way, but from the massive fine grained variety, it was impossible to prepare even an approximately pure sample, so the residue from the coarse platy variety was taken. An analysis of the prepared material, showed that it contained 7,5% nickel, and 1,90% copper. As many samples of the purer pyrrhotite in their original state contain as much as 6 or even 7% nickel; and the particular piece examined, slightly over 7%, it is clear that no appreciable concentration has been effected.

In regard, therefore to the condition of its nickel, the Sohland ore differs markedly from that of Sudbury. At the present moment it cannot be said that pentlandite *does not* exist in the Sohland ore. But if it does, it must be in a very fine state of division, and intimately and uniformly distributed through the pyrrhotite, so that it cannot be separated by magnetic means.

As another alternative we may fall back on the assumption that the nickel is an essential constituent of the pyrrhotite, isomorphously replacing the iron. A third possibility is that the nickel is present in a definite mineral, which is itself magnetic, and so does not allow a separation from pyrrhotite by means of a magnet.

The results of these investigations, I submit in the hope, that they may throw some additional light on this interesting and important class of ore-bodies, and perhaps help to clear up some of the disputed points in the science of Ore-Deposits.

ANTHRACITE BREAKER OF THE PACIFIC COAL COMPANY, LIMITED, BANKHEAD, ALBERTA.

By Lewis Stockett and B. R. Warden,
Bankhead, Alberta.

A description, with drawings and photographs, of the building and machinery recently erected for the preparation of the anthracite coal mined by the above named company, may be a matter of interest to the members of the Institute, and should be a matter of pride to Canadians, as it is the first plant of this kind to be erected on Canadian soil.

The geology of the field has been described in other papers contributed to the Institute, and it is not therefore the purpose of this article to give any description thereof. Seven of the seams have been developed up to date, and a cross-cut tunnel driven across the measures will develop the remaining seams, the prospecting work having shown that there are at least twelve seams in the basin. Of the seven seams opened up, four are being worked; one is used for the main haulage road and air courses and two are not being worked on account of the friability of the coal and the large percentage of the smaller sizes they make, the market for which is at the present time somewhat limited, but is being extended as the proper appliances for burning these small sizes under boilers are being put in.

An average analysis of the coal is as follows:—

Moisture	0.50	
Volatile	8.00	
Fixed Carbon	83.50	
Ash	8.00	
		100.00 per cent.
Sulphur	0.40	
Specific Gravity	1.40	
Ash, White		
British Thermal Units	14,000	

In the preparation of anthracite coal, machinery is required to screen out all the dust, remove all the impurities, such as

rock, sulphur balls, slate and bony coal, and separate it into several sizes. These sizes, conforming very nearly with the practice of the anthracite colleries of Pennsylvania, are divided as follows:—

Broken	through	3″ bars and over		$3\frac{1}{4}$″ round holes.
Egg	"	$3\frac{1}{4}$″	holes and over	$2\frac{1}{4}$″ holes.
Stove	"	$2\frac{1}{4}$″	"	$1\frac{1}{2}$″ holes.
Nut	"	$1\frac{1}{2}$″	"	1″ holes.
Pea	"	1″	"	9-16″ holes.
Buckwheat No. 1	"	9-16″	"	5-16″ holes.
Buckwheat No. 2	"	5-16″	"	$\frac{1}{4}$″ holes.
Buckwheat No. 3	"	$\frac{1}{4}$″	"	$\frac{1}{8}$″ holes.
Dust	"	$\frac{1}{8}$″		

All the sizes are marketed with the exception of Buckwheat No. 3 and the dust, the latter of which, preparations are being made to briquette, and the former will be used under the plant boilers as more and more of the Buckwheat No. 2 is taken by the general market.

The accompanying diagram gives graphically the method used in the preparation. The coal is hoisted to the top of the breaker (100 ft. above the railroad tracks) by means of an endless chain, travelling 60 feet per minute, with hooks spaced 30 feet apart, to engage the axles of the mine cars. This will deliver two cars per minute. The capacity of these cars is something over two tons, giving a capacity of 2,400 tons per day of ten hours, which can be increased by spacing the hooks 20 feet or even 15 feet apart as may become necessary. The empty mine cars are returned down the incline by another endless chain, travelling at the same speed and with hooks spaced 12 feet apart, on to which they are fed by an auxiliary chain so arranged that as the cars are delivered on to the main chain a hook is waiting in readiness for each car and the car is delivered to the chain without shock. The grades of the track are such that the car handles itself, from the time it leaves the top of the uphaul chain until it arrives at the top of the downhaul chain. The tracks at the bottom of the incline also have their grades arranged so that the loads feed into the bottom of the incline and the empties run away from it.

Referring to the diagram:—The coal after passing over a scale which weighs it as it passes, is dumped by means of a cross-over tipple, into a dump chute, and fed by an automatic feeder

regularly over a set of screen bars with 3-inch spaces onto a platform. This automatic feed revolves 1½ revolutions per minute has four compartments, each of which contains about 1,000 lb., of coal, so that it has a capacity of two tons at each revolution, or three tons per minute, and 1,800 tons in ten hours.

On the platform the material is sorted and the rock and slate pushed into the rock bin, the coal is separated, the lumps of pure coal going through a set of rolls and broken up into marketable sizes, and the lumps containing a portion of bone or slate through another set of rolls to be likewise broken up to allow the removal of the pieces of bone and slate. These rolls revolve at 90 revolutions per minute, are 36″ in diameter and 36″ long, and have inserted steel teeth 1¾″ square and 3½″ long, spaced 4¾″ apart and set diagonally.

From here we have three separate and distinct streams of coal, which, on account of their different characters, require different treatment, and by keeping them separate until they reach the loading bins, to be loaded into the railroad cars, they are enabled to get the preparation they require.

The "pure coal" as it comes from the rolls, needs only screening to take out the dust made in the breaking, and to separate it into the different sizes, any pieces of slate or bone which may appear being removed by hand.

The "Bony coal" not only requires this, but also thorough cleaning of the pieces of slate and bone; this is accomplished in the broken and egg sizes, by passing from the screen onto a picking band, from which the impurities are removed by hand picking, the rock and slate going into a conveyor which takes them to the rock bin, and the pieces containing both coal and slate or coal and bone going to another set of rolls to be broken up smaller, so that the coal can be saved in the smaller sizes.

What remains after the broken and egg sizes are taken out, is elevated to the top of the building, and passing over another set of screens, is separated into stove, nut, pea, buckwheat No. 1 and buckwheat No. 2 sizes, the dust going into the dust bin, to be hauled out and dumped on the waste bank at the present time; later on, a briquette plant is to be erected to briquette this dust. The stove coal, after it leaves the screen, goes over a mechanical picker, known as the "Emery" picker, which removes the slate

and bone. The coal from this picker and also the refuse, is picked by hand to save any coal that may be thrown out with the slate, and to remove any pieces of slate which the machine has failed to remove. The coal then passes to the bins, and the refuse to a conveyor to be conveyed to the rock bin. The nut and pea coals are similarly treated, with the exception that with the pea there is no hand picking. The No. 1 Buckwheat, as it leaves the screen, passes over slater bars which removes the flat pieces, and as these flat pieces are nearly all slate, cleans the coal with very little loss. The No. 2 Buckwheat is found to be sufficiently clean without any further preparation, and goes direct to the bin.

The "mine run" coal, that portion which passes through the 3″ bars above the platform, is conveyed to the broken screen by means of a chute, the bottom of which has $\frac{1}{4}$″ square perforations to remove the dust, which falls into the dust bin; the broken screen removes the broken size, the remainder passing over 3-16″ round perforations on the bottom of the broken screen, which removes the remaining dust. This broken coal joins the broken coal from the "bony coal" stream on the same picking band to have the refuse removed. The egg size has similar treatment, and the remainder is elevated to the top of the building, to go through a like treatment as the "bony coal" stream, with the exceptions that, containing a larger proportion of impurities, it has double the number of Emery pickers and hand pickers, and the nut and pea sizes pass over slater bars which remove the flat pieces.

The screens on the "mine run" side are 6 ft. wide and 12 ft. long, with the exception of the buckwheat screens, the No. 1 being 5 ft. wide and 18 ft. long, and the No. 2, 6 ft. wide and 18 ft. long. Those on the "pure coal" and "bony" sides are 4½ ft. wide by 12 ft. long, with the exception of the buckwheat screens, which are the same size as those on the mine run side. They are built of steel plates and angle iron, suspended on 5-8″ chains and are driven by eccentrics having 6″ travel and running 100 revolutions per minute. The pitch of the screens is 2 inches per foot.

The "mine run" elevator is of the continuous discharge type, with deflecting shafts to give a more perfect discharge; having

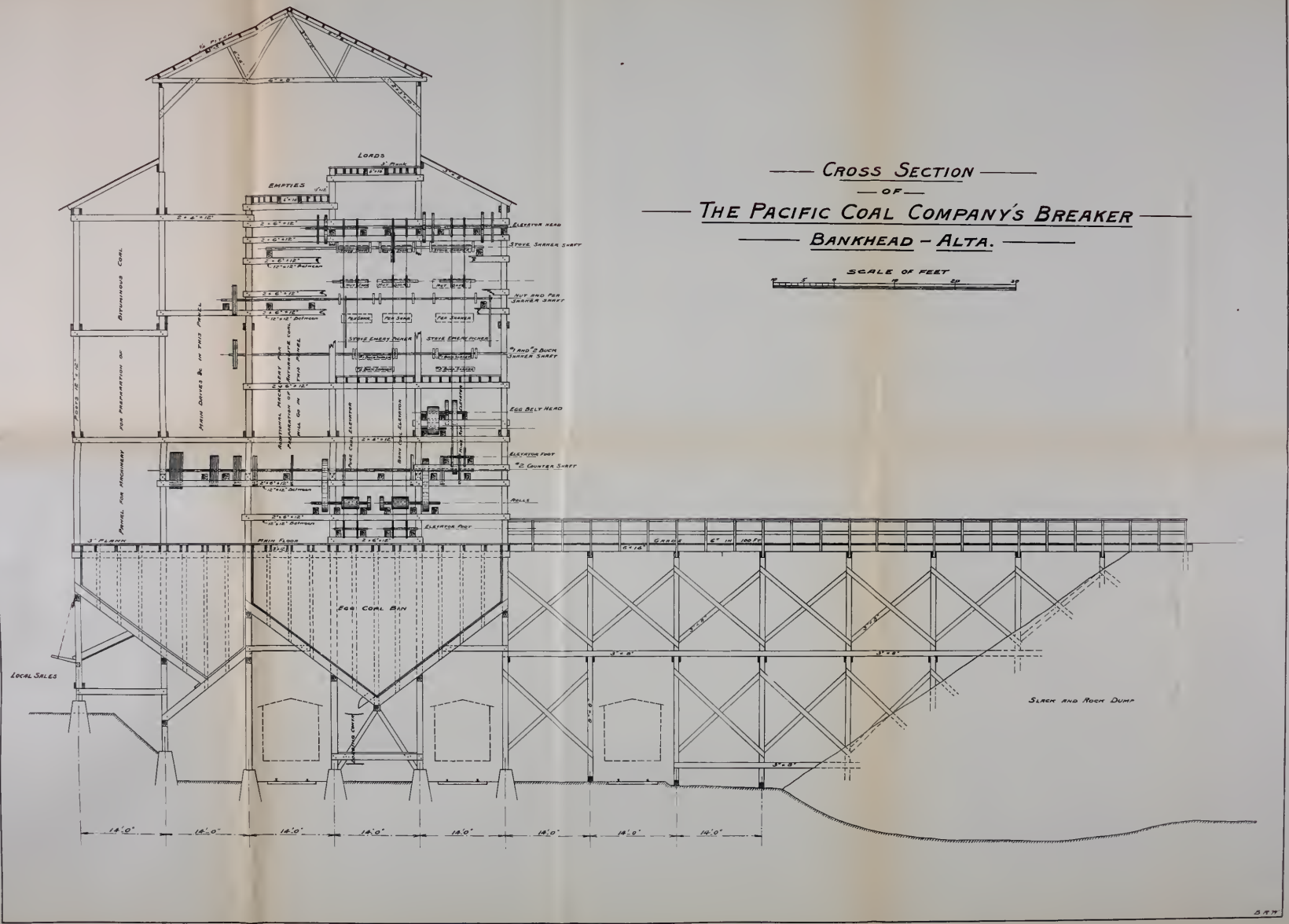
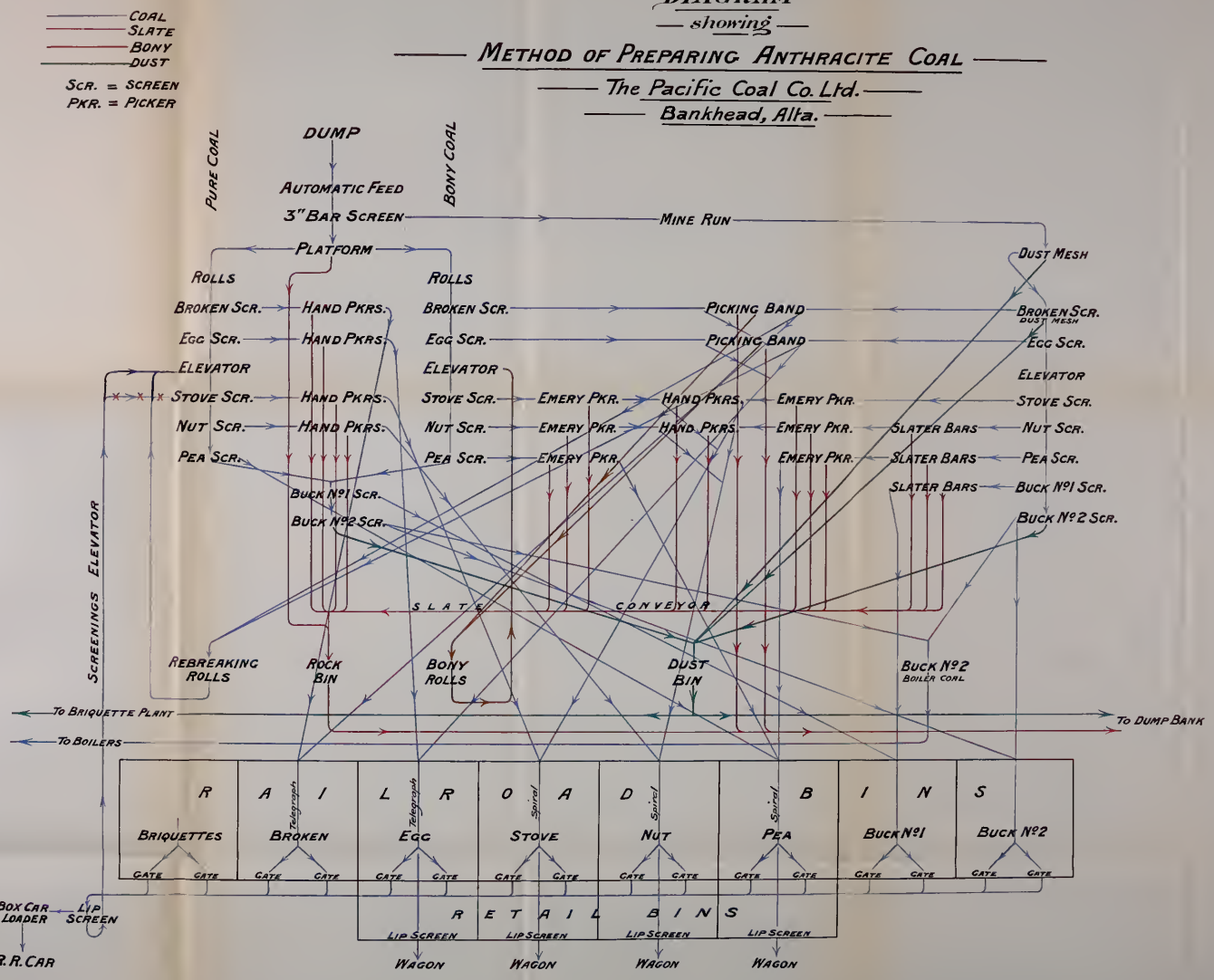
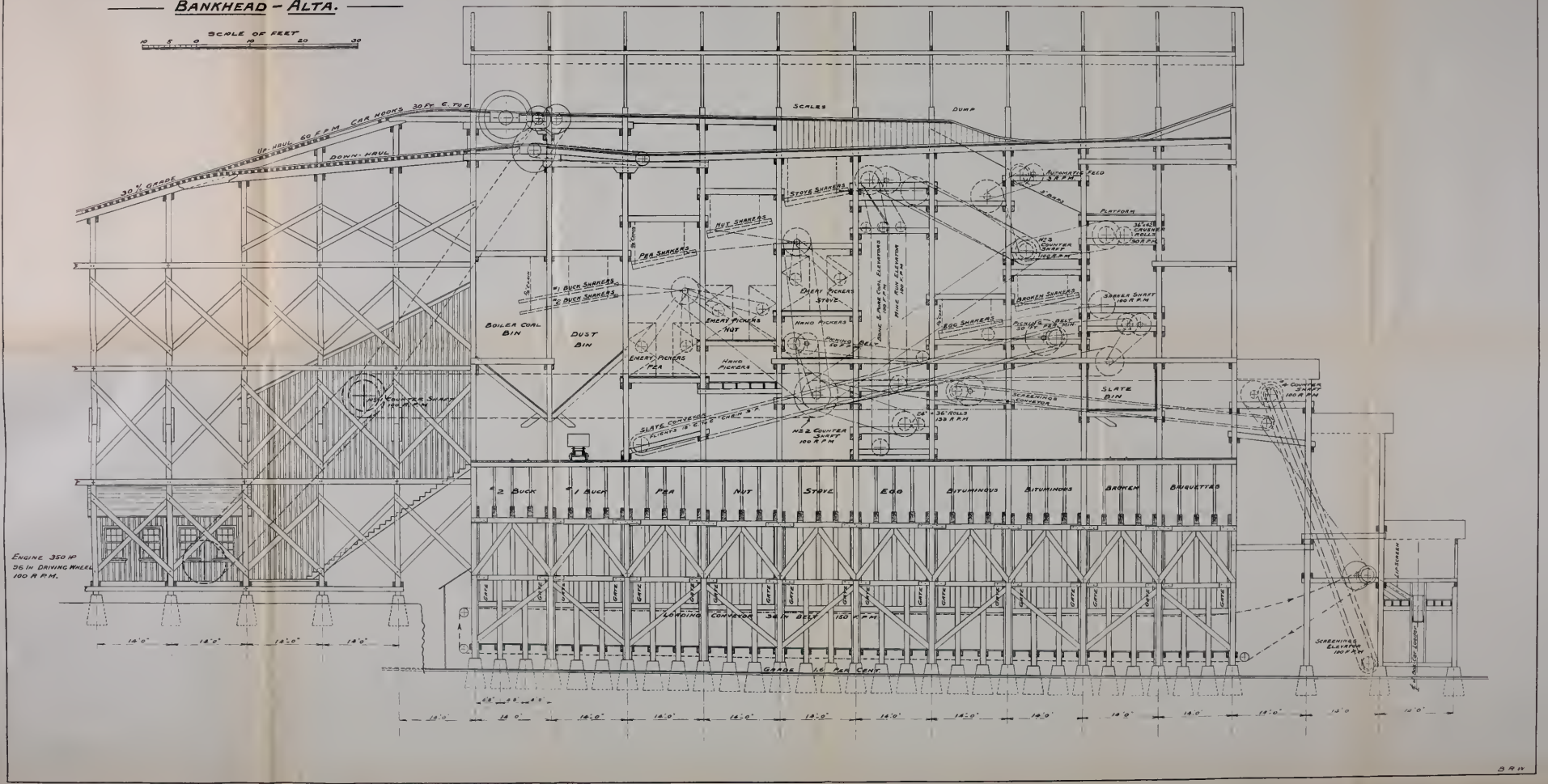

Cross Section
of
The Pacific Coal Company's Breaker
Bankhead - Alta.
SCALE OF FEET
Lords
Empties
Elevator Head
Stove Shaker Shaft
Nut and Pea Shaker Shaft
Egg Belt Head
Elevator Foot
Rolls
Elevator Foot
Main Floor
Egg Coal Bin
Local Sales
Slack and Rock Dump
14'-0"
14'-0"
14'-0"
14'-0"
14'-0"
14'-0"
14'-0"
14'-0"

DIAGRAM
showing
METHOD OF PREPARING ANTHRACITE COAL
The Pacific Coal Co. Ltd.
Bankhead, Alta.



Longitudinal Section
of
The Pacific Coal Company's Breaker
Bankhead - Alta.

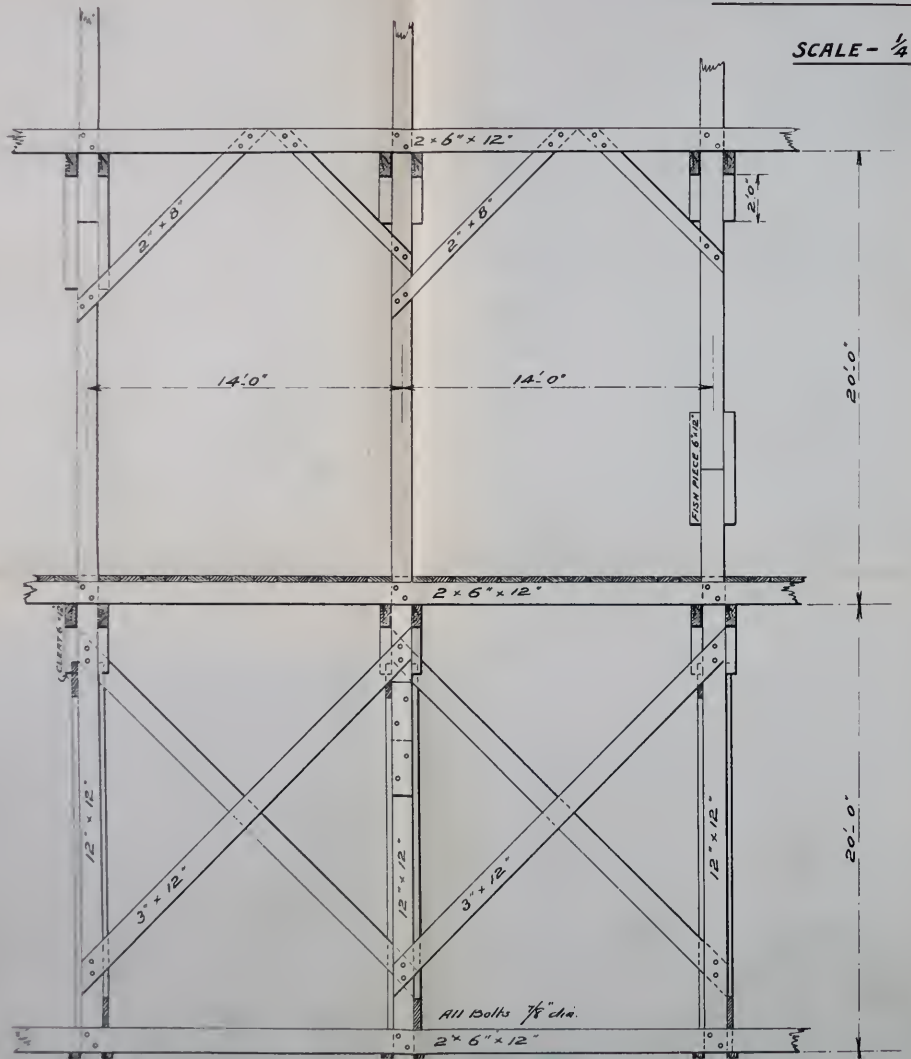


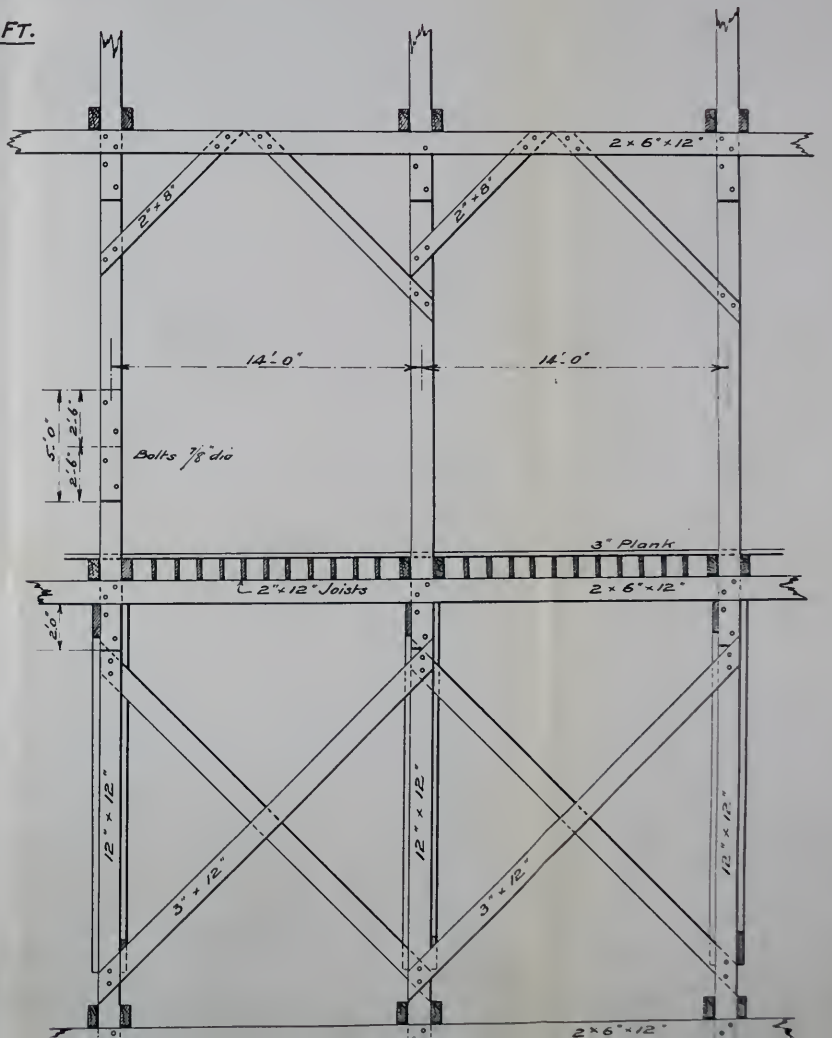
— System of Framing —

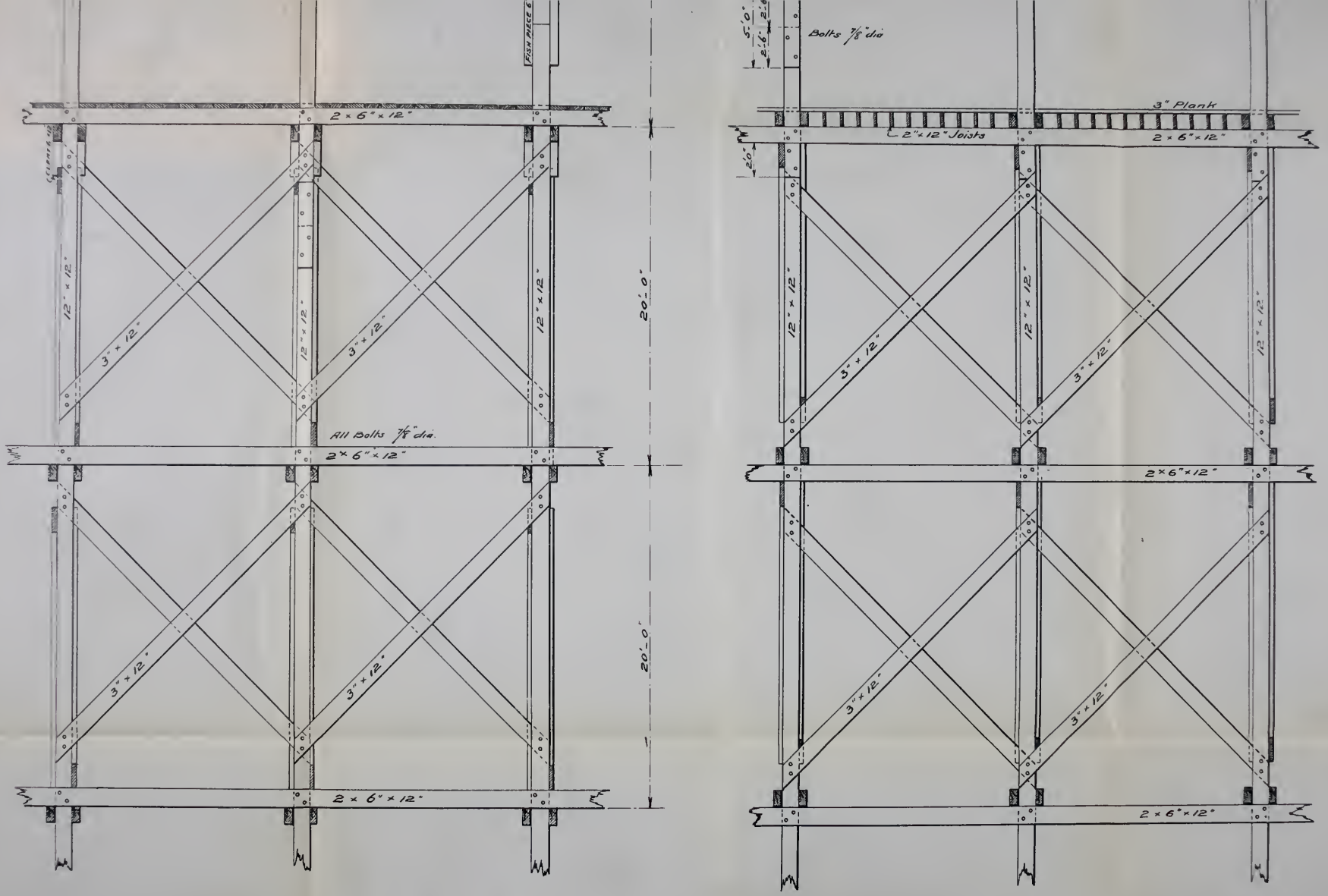
— The Pacific Coal Company's Breaker —

— Bankhead, Alberta. —

SCALE - 1/4" = 1 FT.






FISH PIECE 6"
2 × 6" × 12"
12" × 12"
3" × 12"
12" × 12"
3" × 12"
12" × 12"
All Bolts 7/8" dia.
2 × 6" × 12"
3" × 12"
3" × 12"
2 × 6" × 12"
20'-0"
20'-0"
5'-10"
2'-6"
2'-6"
Bolts 7/8" dia
3" Plank
2"×12" Joists
2 × 6" × 12"
2'-6"
12" × 12"
3" × 12"
12" × 12"
3" × 12"
12" × 12"
2 × 6" × 12"
3" × 12"
3" × 12"
2 × 6" × 12"

buckets 24″ x 12″, each bucket containing 80 lbs. of coal when level full, the speed is 66 buckets per minute, giving a capacity of about 2½ tons per minute, or 1,500 tons per day of ten hours. The "pure" and "bony" coal elevators are of the same type as the "mine run" elevator and both alike as to size, having buckets 16″ x 8″, containing 22 lbs. of coal when level full, and at a speed of 100 buckets per minute, give a capacity of one ton per minute, or 600 tons for the ten hours. The combined elevating capacity of the three elevators is 2,700 tons per day of ten hours.

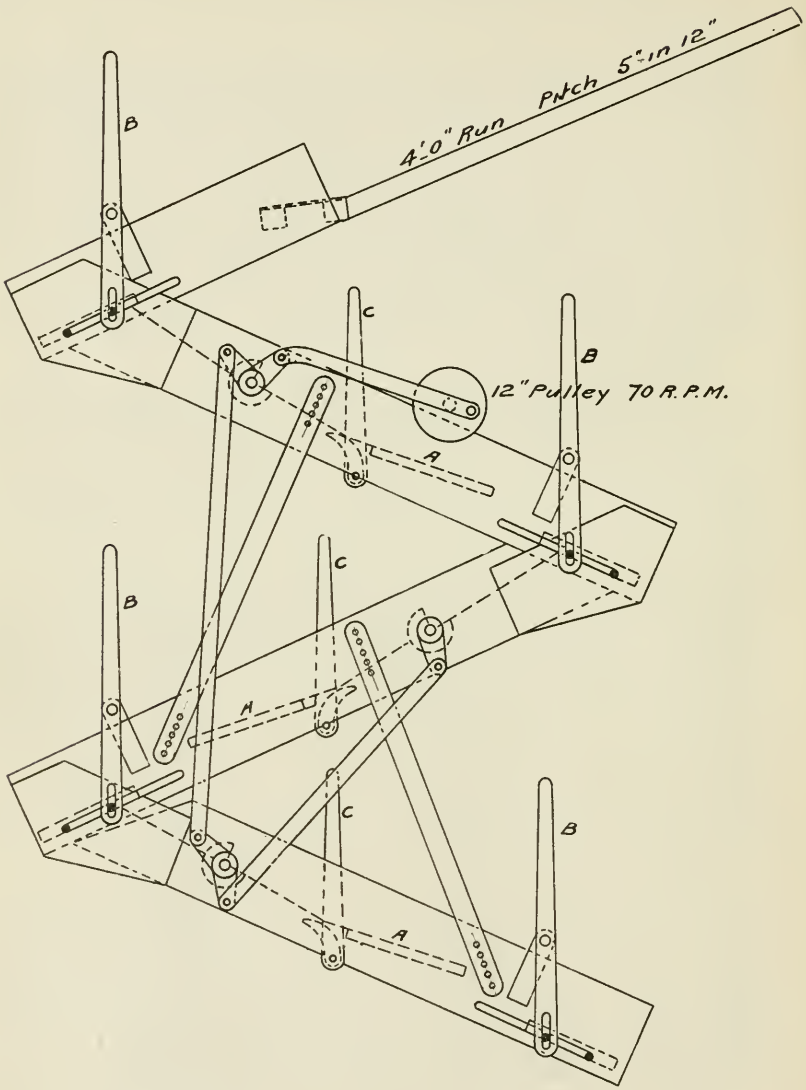
The Emery pickers are illustrated in the accompanying cut. The material to be separated is fed over the inclined chutes by feeders. The lower ends of these chutes are slate slabs, and as the material is fed over them, the difference in the specific gravity of the coal and of the refuse, and also the difference in shape, causes a difference in the friction, (that of slate being the greater) as it passes over the slate slab, which retards the movement of the slate so that it falls into the opening and thence into the slate chute, the coal acquiring velocity enough to jump the opening at the bottom and pass on into the coal chute. Both the pitch of the slate slab and the width of the opening are readily adjustable by means of levers, and these are adjusted to meet the requirements of the coal and changed when found necessary. The feeders oscillate 65 times per minute, and it is to this regularity in the feed that the success of the machine is largely due. The capacity of each picker is 100 tons per day of ten hours.

The slater bars are shown in the accompanying cut. These are set on the end of a screen, or in a chute, where the coal can slide over them. The flat pieces fall through the narrow openings, and as nearly all of the flat pieces are slate, by getting the proper width of opening all of the flat slate is removed, leaving those pieces of slate which are the same size as the pieces of coal, to be dealt with by the Emery picker and hand picking.

The hand picking is done on picking bands for the larger sizes, and on inclined chutes set at pitches varying from 4″ to 5″ to the foot for the smaller sizes. Chinamen and boys are employed for this purpose.

A set of re-breaking rolls, 24″ in diameter and 36″ wide, with 1¼″ square steel teeth 2″ long, set diagonally and spaced 3¼″,

EMERY - SLATE - PICKER



A. Slate Slab.

B. Lever to regulate space across which pure coal has to jump after passing over slate slab.

C. Lever to regulate pitch of slate slab.

FIG. 8.

Scale 1 In. = 1 Ft.

revolving at 133 revolutions per minute, is provided for re-breaking the broken and egg sizes into stove and smaller sizes, when the market conditions are such that a larger proportion of these sizes is required than is ordinarily made.

A set of bony rolls of the same diameter and width and running at the same speed as the re-breaking rolls, with steel teeth 1″ square and 1½″ long, set diagonally, and spaced 1 15-16″. is provided to break up the pieces containing both coal and bone or coal and slate, picked from the broken and egg picking bands.

The material from the re-breaking rolls is elevated, in the pure coal elevator, to the screens above, to be separated into sizes, and the material from the bony rolls is likewise elevated in the bony elevator to the screens above to be separated into sizes and cleaned.

The stove, nut and pea sizes, after preparation, are conveyed into the bins by means of spirally inclined chutes to save the breaking of the coal. These inclined chutes extend from the top to the bottom of the bins, and the coal slides down them until it reaches the pile of coal in the bottom of the bin or wherever it may be. The broken and egg sizes are conveyed to the bin by straight inclined chutes, called telegraphs; it having been found that the spirally inclined chutes would not work well with these larger sizes.

From the bins the coal is drawn out through gates to a belt conveyor, 36″ wide and running the full length of the building at a speed of 150 feet per minute, which conveys it to a lip screen set on an inclination, with different sized perforations for the different sizes of coal. This screens out any dust and smaller sizes that may be in the coal before it passes into open cars direct or to the Box Car Loader, to be loaded into box cars. From this lip screen an elevator conveys the screenings to the top of the bins, where a conveyor takes it to the "pure coal" elevator, to be elevated to the screens above and separated into such sizes as it will make.

This lip screen elevator is of the same size as the "bony" and "pure coal" elevators, simply not to have too many different sized pieces of machinery, but is run at one-half the speed.

The screenings conveyor is a flight conveyor, working in an iron trough with 16″ x 8″ flights every 36″, and having a speed of 100 feet per minute.

The slate and other refuse from the various picking machines and hand pickers slides by gravity into a flight conveyor, similar to the screenings conveyor, except that the flights are spaced 18″ apart, giving double the capacity.

The box car loader is the Victor loader, (see Figure 9) and is run by its own engine with steam from the main boiler plant.

Power is furnished for all the rest of the machinery, including the hoisting on the incline, by a 16″ and 28″ x 36″ cross compound horizontal engine, running at 100 revolutions per minute, using steam at 120 lbs. pressure in the high pressure cylinder and capable of developing 350 horse power.

All of the drives are 1½″ Manilla rope, except a few short drives where rubber belting is used. The main drives are continuous ropes with tension carriages, and the side drives are loops, the plan being followed of putting one more loop on each drive than was necessary, so that in case of one coming off or breaking, the plant could still continue to run. Splicing, and shackles of different kinds have been tried on the ropes with the result that the splicing, while troublesome until a rope gets stretched, and taking longer to make, has been found the most satisfactory. All of the main lines of shafting in the breaker run at 100 revolutions per minute, from which the required speeds for the different machinery are made by a difference in the sizes of the pulleys or rope wheels, and where a very slow speed is needed, by pinions working into larger spur wheels.

The foundations of the building and machinery are all of concrete, the gravel and sand for which were had from the excavations. Eight hundred and fifty barrels of cement were used. The posts of the building and inclines rest directly upon piers.

The timber used was Coast Fir, about 1,000,000 feet B.M. being used; no mortises and tenons, gaining or dapping were used, and the style of framing, which is shown in the accompanying drawing, may be described as continuous posts, spliced together, with all cross timber, braces, etc., bolted on, these cross timbers when necessary being further supported by wooden brackets bolted on. As a square,

crosscut saw, auger, hammer and monkey wrench were the only tools used, it gave a quicker and cheaper method of erecting. There is not the settling due to rotting of mortises and tenons, the drying out of the timber or the load being carried across the grain of the wood. There is also a greater stiffness, which in a building of this kind, where there is so much moving machinery and vibration resulting therefrom, is very necessary. As the timber dries out, all that is needed is to go over the bolts and tighten them up. The building has proven to be very solid and free from shaking, either from the movement of the machinery, or the wind pressure from some very severe winds which we have had since erection.

The building is heated by direct steam in coils of 2″ pipe, some 5,000 lineal feet being used for the purpose. The lighting is done with 16 C.P. incandescent electric lights, some 200 being used. For fire protection there are two fire plugs on the outside of the building, with two connections on each plug for 2½″ fire hose, the water pipes having a head of 400 feet. Also two stand pipes, one at either end of the building, with hose connections at three different heights, having a hose and nozzle always attached and requiring but the opening of a valve. Sixty fire buckets set in convenient racks and standing full of water are ready for immediate use on the breaking out of a fire.

The rock and dust are hauled out over trestles in iron dump cars holding 1½ tons each, by a 6″ x 10″ compressed air locomotive weighing five tons, to the waste bank. The dust will later be taken by a flight conveyor to the briquetting plant, and the resulting briquettes returned to the breaker by the same method.

Every car of coal loaded is sampled and tested for the percentage of slate, bone and small sizes contained in it; if it does not come within the following table of standards adopted by the Pennsylvania anthracite market, it is unloaded into the breaker to be recleaned:—

	Slate. Per cent.	Bone. Per cent.	Undersize. Per cent.
Broken	1	2	0
Egg	2	2	0
Stove	4	3	0
Nut	5	5	15
Pea	10	—	15
Buck. No. 1	15	—	20
Buck. No. 2	—	—	30

Duplicates of all the pieces of machinery which are liable to break or wear out have been provided and are kept conveniently placed so as to be quickly put in.

The accompanying drawings, showing ground plan, longitudinal section and vertical section, will give more in detail the building and the placing of the machinery in it, and the photographs will show the progress of the work.

Excavation was commenced	April 3rd,	1905
Foundations were commenced	April 14th,	"
Framing was commenced	May 27th,	"
Erection was commenced	May 31st,	"
First machinery placed	July 24th,	"
Foundations finished	July 25th,	"
Erection finished	October 14th,	"
Machinery finished	October 28th,	"
Breaker tried	November 6th,	"
Breaker started up	November 13th,	"

The cost of the breaker and incline is shown in the table below:—

General Expense	$ 3,076.73
Labor	34,829.35
Lumber	15,709.97
Cement	4,238.90
Iron and Hardware	6,209.34
Machinery	30,262.45
Freight	17,414.19
Duty	4,740.08
Power, Tools, etc.	815.66
Pipe and Fittings	1,561.72
Electric Supplies	317.19
	$119,175.58

The force required to man the breaker is as follows:—

Breaker engineer	1
Oiler	1
Bottom man	1
Car Oiler	1
Spragger	1
Top man	1
Weighman	1
Dumpers	2
Platform men	5
Screen men	6
Emery picker men	3
Hand pickers	35
Dirt bank men	4
Locomotive engineer	1
Locomotive switchmen	2

Laborers	5
Box car loader engineer	1
Box car loader men	4
Foreman	1
Carpenter and Repairman	1
Weighman	1
	76

The breaker is not complete until another side of "mine run" machinery will have been installed, which will require another dump, bar screen, platform, screens and elevator; it will then be abundantly able to handle 2,000 tons of material per day of ten hours.

It will be noticed that after the additional "mine run" machinery is installed, there is still a vacant panel in the breaker and also a set of bins; these are being reserved for bituminous coal, the prospecting having shown that there are bituminous seams on the property and which will be reached in time. We will then have something unique in coal preparation; that is, both anthracite and bituminous coal from the same mine and loaded from the same building.

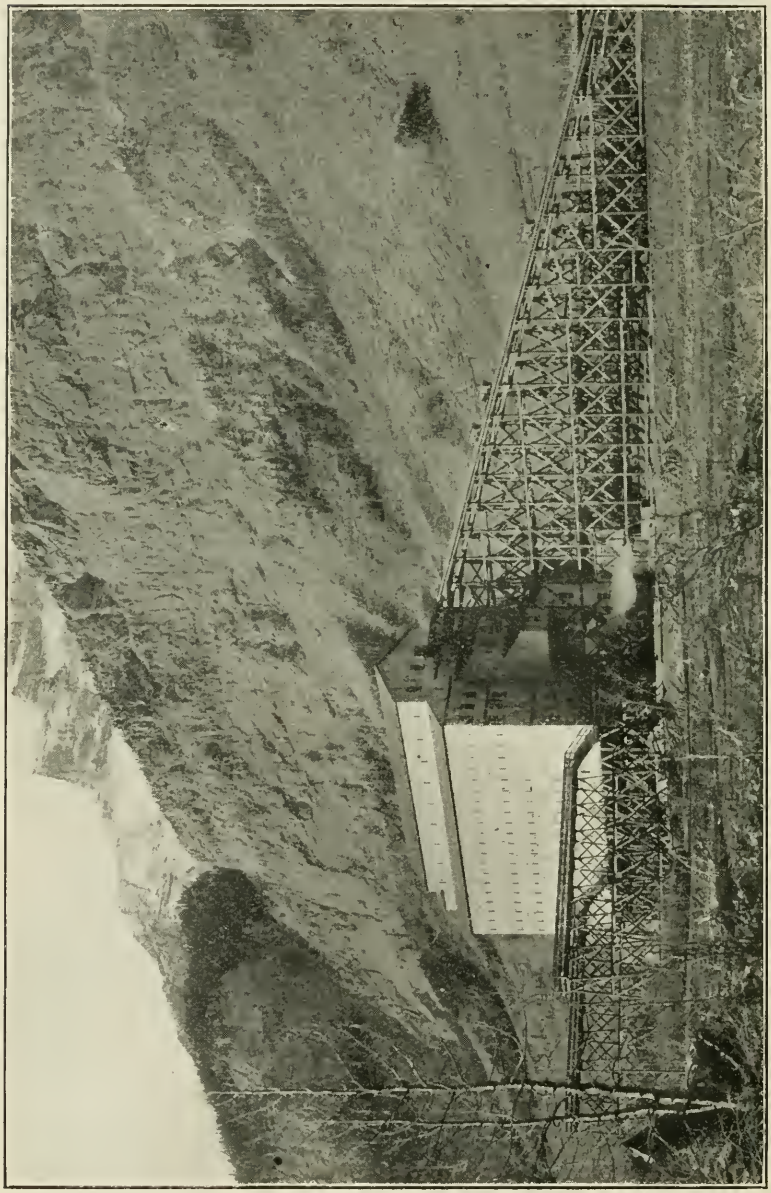
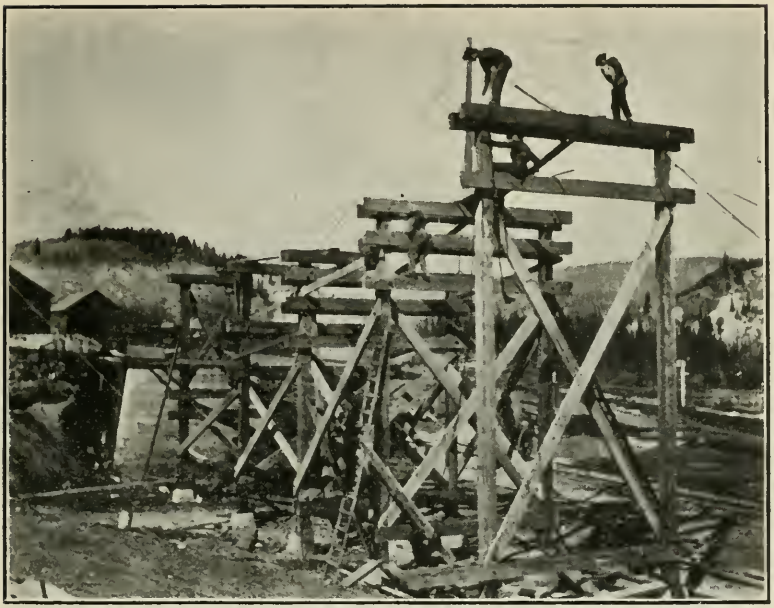


FIG. 1—Anthracite Breaker, Pacific Coal Co., Ltd., Bank Head, Alta.



Incline, May 31st.

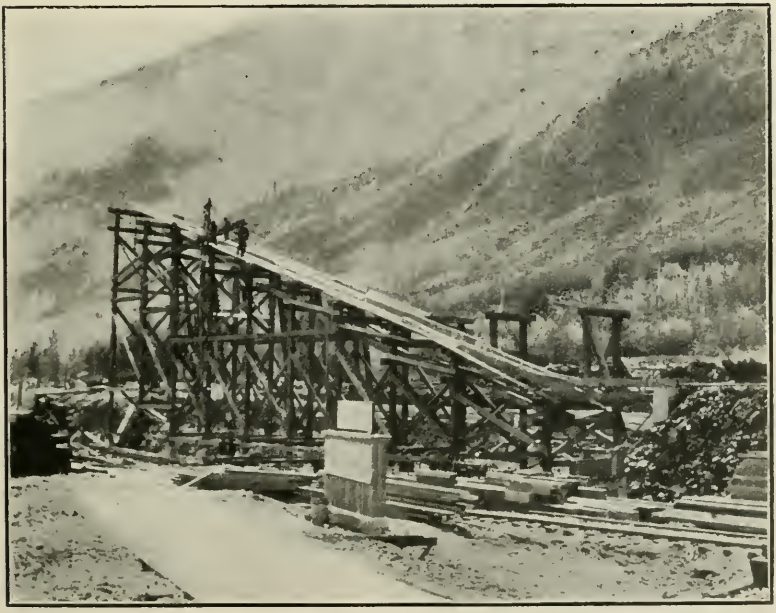
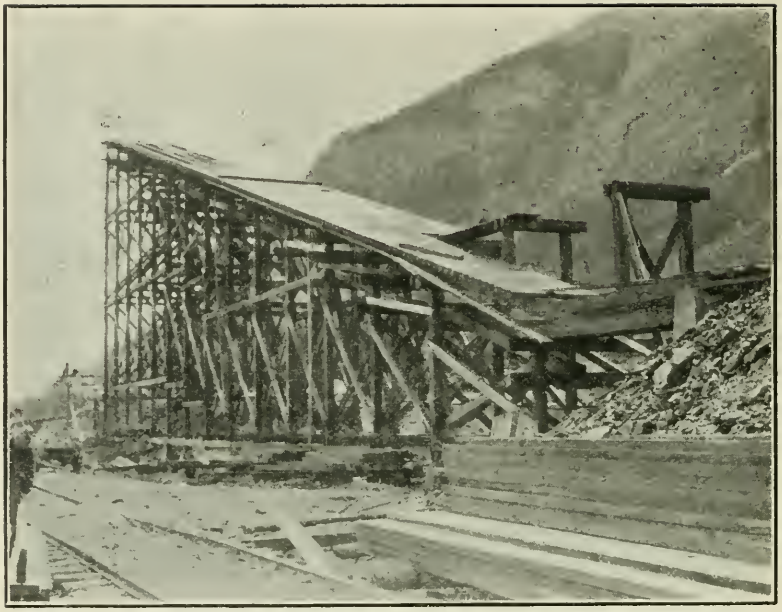


FIG. 2—Incline, June 7th.



Incline, June 13th.

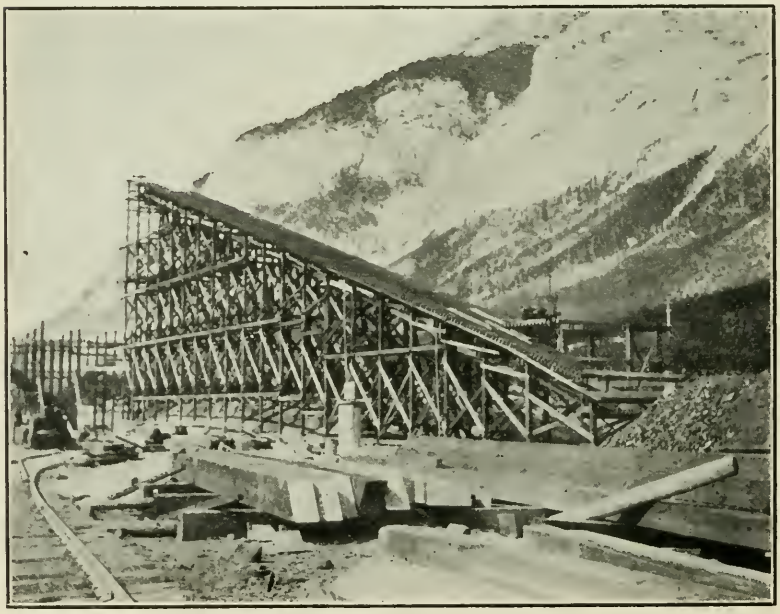


FIG. 3—Incline finished, June 30th.

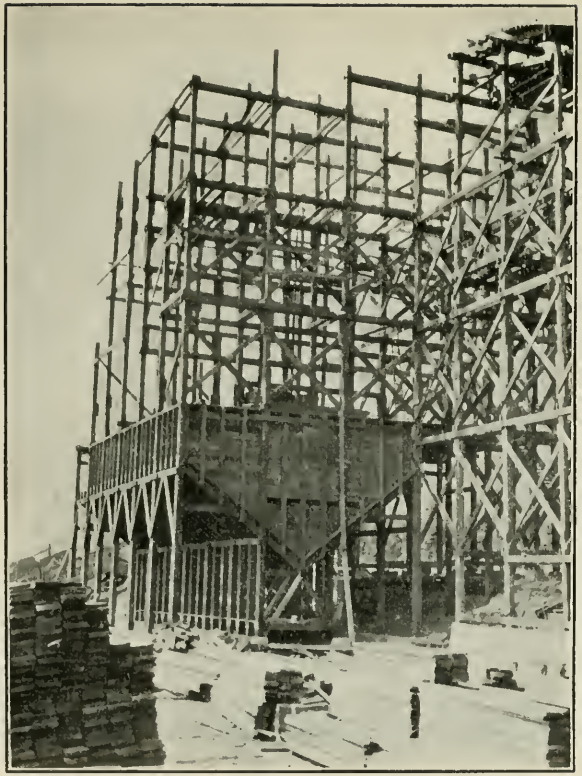
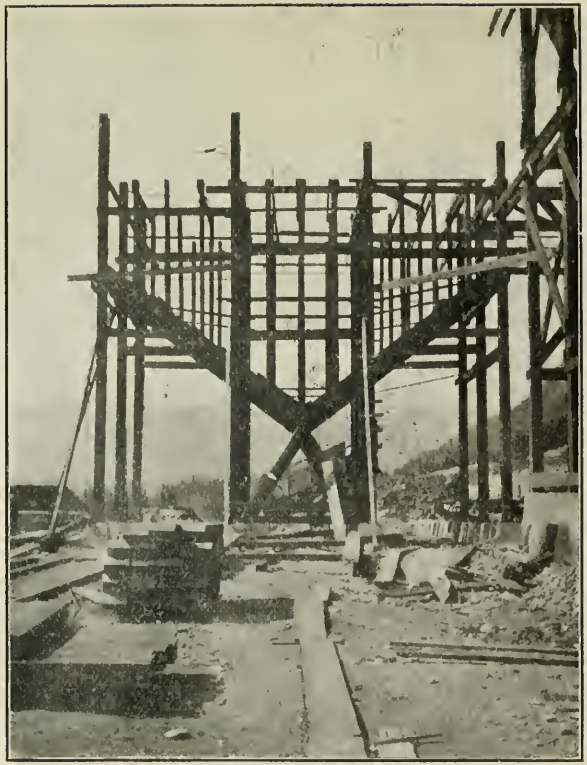
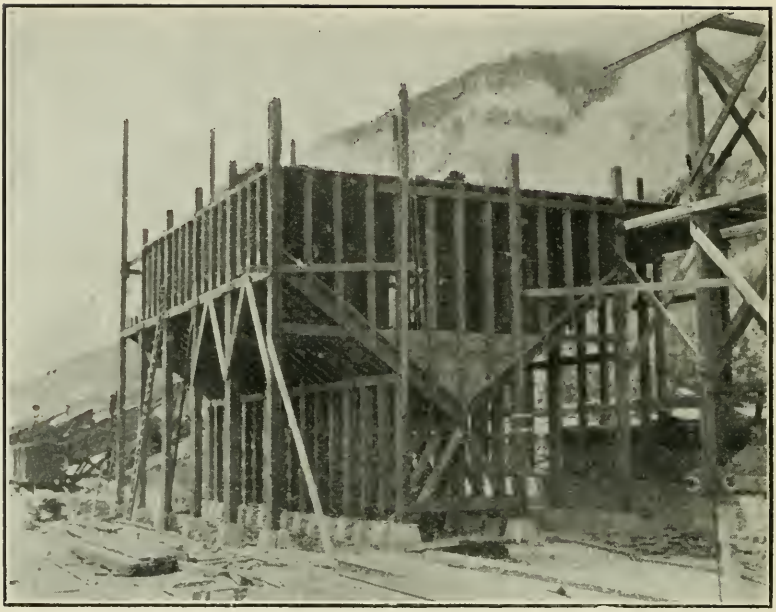


FIG. 4—Breaker, July 31st.



Breaker, July 8th.



Breaker, July 15th.

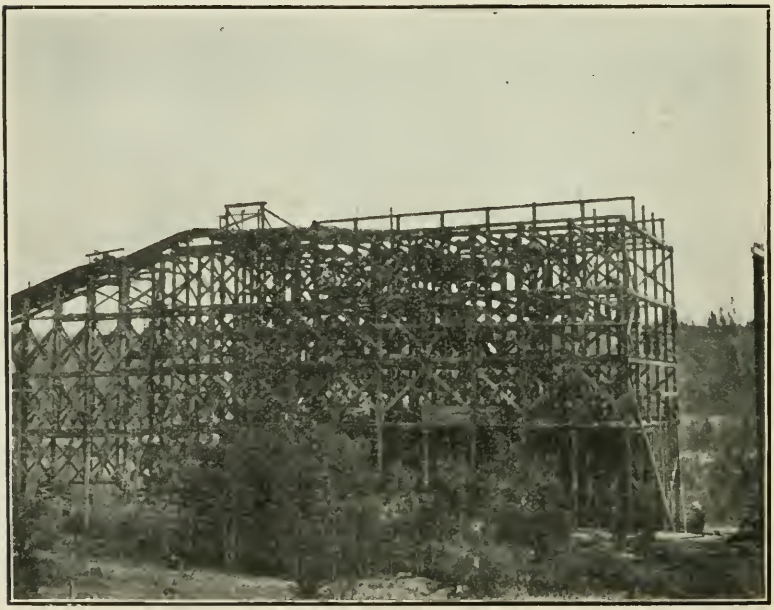
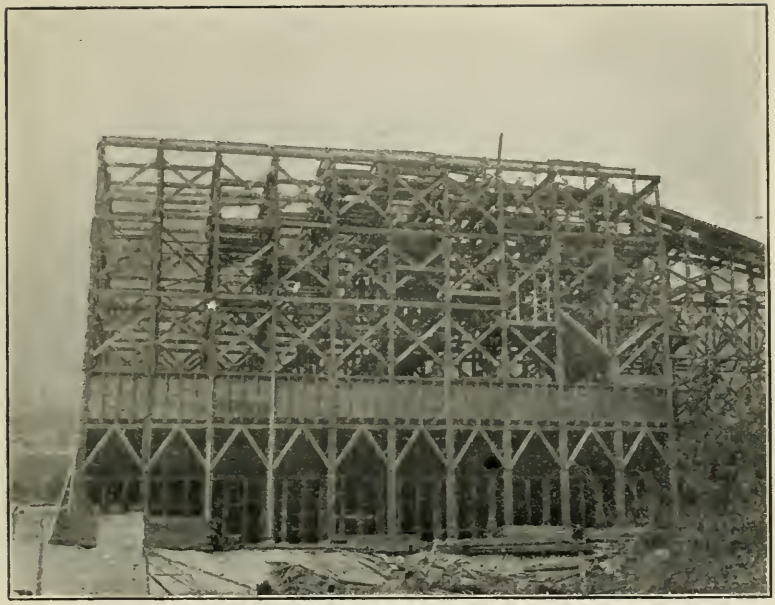


FIG. 5.—Breaker from West, Aug. 23rd.



Breaker from East, Aug. 23rd.

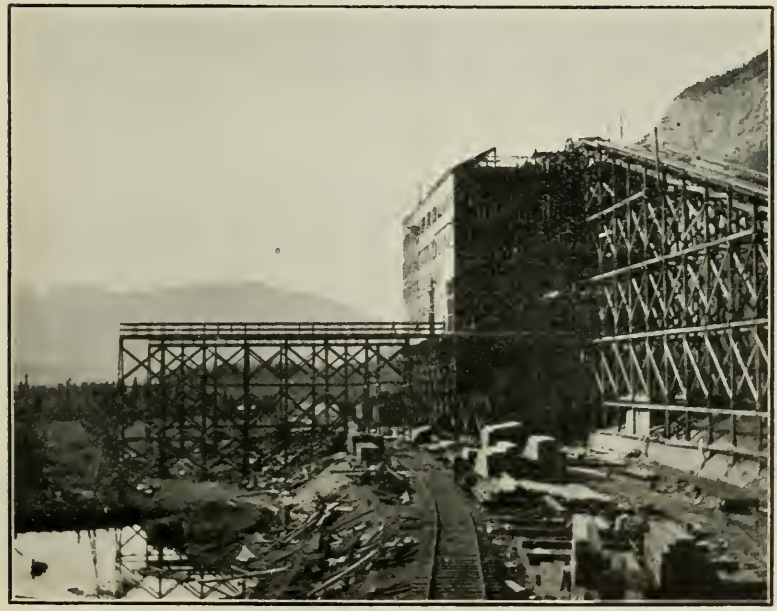
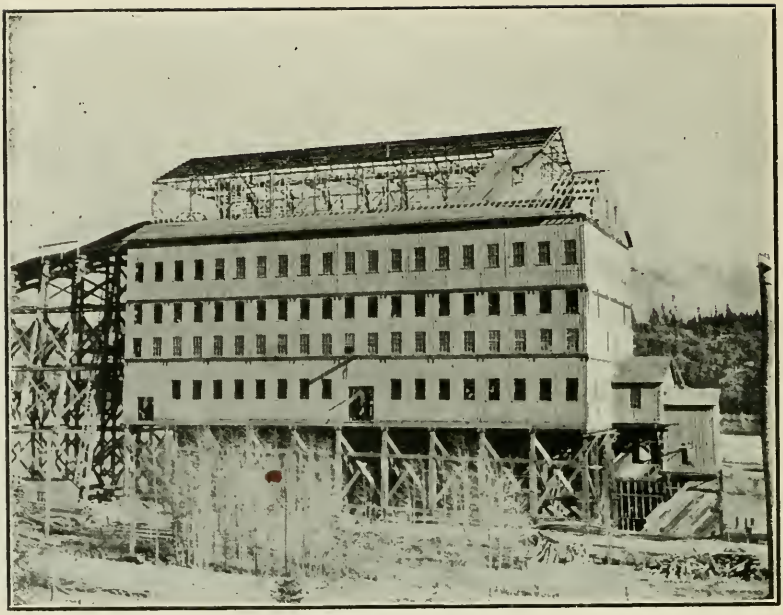


FIG. 6—Breaker, Sept. 17th.



Breaker, Oct. 1st.

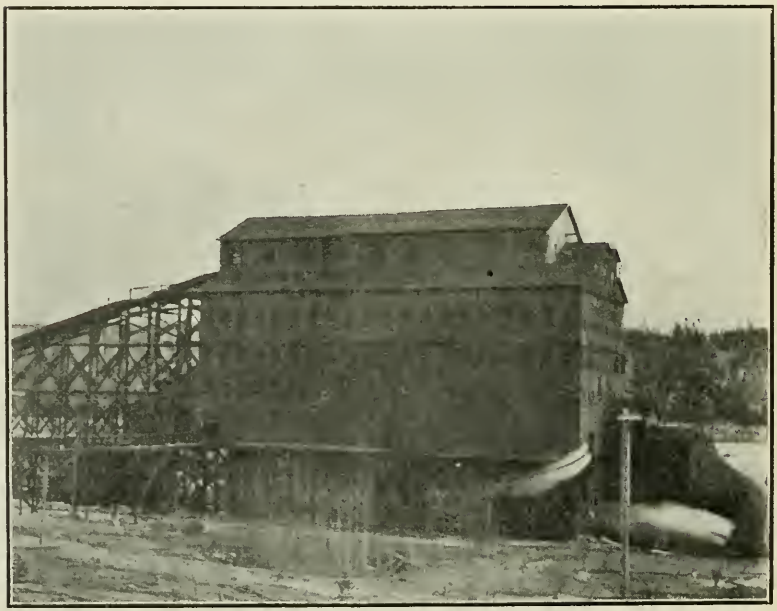
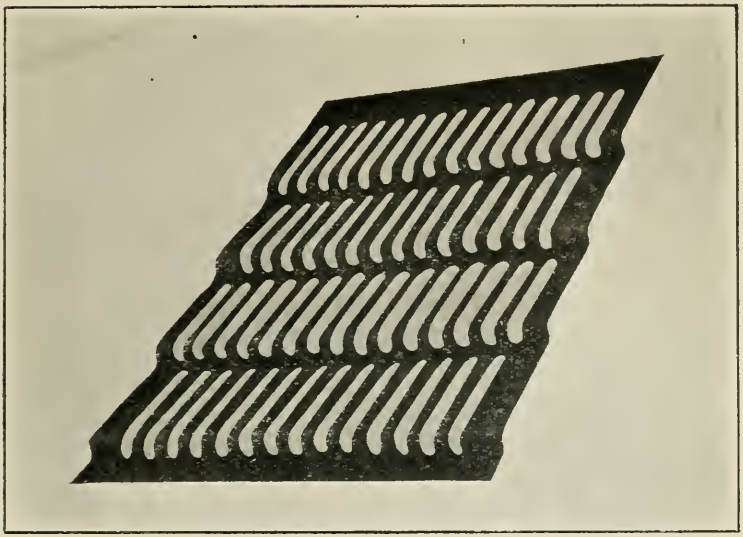


FIG. 7—Breaker completed, Nov. 6th.



Slater Bars.

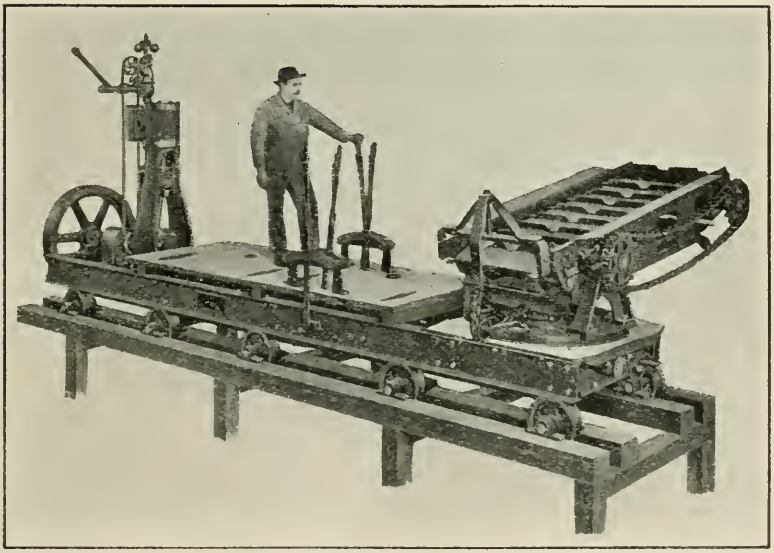


FIG. 9—Victor Box Car Loader.

THE RESPONSIBILITY OF MINING ENGINEERS AND MINING DIRECTORS.

By H. J. Carnegie Williams.

The notification in the newspapers that during the recent session, a bill making the Company laws of the Province uniform with those of the United Kingdom, was again brought forward in the Ontario Legislature, and read for the first time and has now become law, shows that the question of responsibility is regarded as most important. The measure, if successful, will put all promotions on the same basis, and give the same safeguards as those obtaining in the Old Country, thus serving not only as a protection to individuals, but also obviating, it is hoped, any such notice as this seen lately in an English paper:—"This, we note, is a Colonial Company, incorporated by letters patent in Ontario, and not a registration under our Companies Acts."

This Act will *inter alia* do away with the issue of shares at a discount, which is always a debatable question, as it is claimed, and rightly, that it only means that sufficient shares will have otherwise to be created, so that an allotment of fully paid up shares as a bonus will be made to those who risk their money in an unproved enterprise, such as a new mining company generally is.

But doubtless the most important feature will be the inclusion of clause 28 of the Companies Act, 1900, entitled *False Statements*, viz:—"If any person in any return, report, certificate, balance-sheet, or other document, required by or for the purpose of this Act, wilfully makes a statement false in any material particular, knowing it to be false, he shall be guilty of a misdemeanour, and shall be liable on conviction or indictment to imprisonment for a term not exceeding two years, with or without hard labour, and on summary conviction to imprisonment for a term not exceeding four months, with or without hard

labour, and in either case to a fine in lieu of or in addition to such imprisonment as aforesaid—Provided, that the fine imposed on summary conviction shall not exceed £100."

Not only in this country, but in the neighbouring United States the matter is attracting attention, and in the current number of the *Engineering and Mining Journal*, New York, Feb. 24th, 1906, the able editorial entitled "Fake Mining Schemes," will be read with interest.

This subject is one that every mining man must come in contact with in his profession, and therefore we should endeavour not only to safeguard our own reputation, but also to enable directors to be thoroughly satisfied that before sending in a report we have verified all facts as closely as possible. It is hardly credible that the following statement has been published, but it has the authority of Mr. Aubury of the California State Bureau, and therefore can be relied upon implicitly.

The effusion relates to the Clover Creek Quicksilver Mine, and a paragraph reads:—

"Gee Whilekins! If you commence talking about that pay streak you will get heart failure at once. Just think if you had enough of it ready, and could run our reduction works one day on this rich pay streak ore, you would produce $52,080. If you could measure it by saying it was 6 inches wide, 600 feet long, and 100 feet deep, you would have nearly $2,000,000 value. If you thought it was over a mile long, as we know our ore bodies are, and that it continued down, say 5,000 feet, as I believe it does, we would then have six hundred and twenty billion dollars."

Mr. Aubury has evidently put a stop to this clap-trap, by sending one of his assistants to examine the mine, with the result that the United States postal authorities are about to take a hand in the matter by interrupting the company's mail.

This is an exaggerated specimen of what a report should not be, but many mining engineers have had to examine statements based upon the imagination. Personally, the author remembers an instance where a level was driven 80 feet on a gold quartz vein, with about 60 feet of backs, the weight of the ore estimated, and there were some surface outcroppings at irregular intervals extending over half a mile, really small ore chutes. The published report described the ore body as 2,640 feet in

length, five feet in width, and 2,000 feet in depth, and all these dimensions nicely multiplied by the assay value, gave a result running into many millions.

The London Institution of Mining and Metallurgy, Vol. X (1901-1902) of the Transactions has published the valuable paper by J. D. Kendall, entitled "Ore in Sight." This led to a most important discussion, so important that a committee was appointed to reconcile the various views taken by members, and by order of the council, the following circular was sent to all the members, two copies sent with original manuscript. It is one that every mining engineer should have prominently before him, and endeavour to act up to, by doing so he will keep the confidence of his employers, and prevent their suffering any of the penalties imposed by the Companies Act, 1900, if it becomes the law not only in Ontario, but in Canada.

"ORE IN SIGHT."

"The Council of the Institution of Mining and Metallurgy, recognising the great importance to the mining industry and to the public in general, of the subject dealt with in the paper on 'Ore in Sight,' by Mr. J. D. Kendall (*Transactions*, vol. X), appointed a committee to consider what steps the Institution might usefully take in defining the term 'Ore in Sight.'

"The views expressed by leading members of the profession showed a great divergence of opinion as to the definition of the term.

"After due consideration and discussion, the Council came to the following decision:—

"1. That members of the Institution should not make use of the term 'Ore in Sight,' in their reports, without indicating in the most explicit manner the data upon which the estimate is based; and that it is most desirable that estimates should be illustrated by drawings.

"2. That as the term 'Ore in Sight' is frequently used to indicate two separate factors in an estimate, namely:—

"(*a*) Ore blocked out—that is, ore exposed on at least three sides within reasonable distance of each other; and

"(*b*) Ore which may be reasonably assumed to exist though not actually blocked out;

these two factors should in all cases be kept distinct, as (*a*) is governed by fixed rules, whilst (*b*) is dependent upon individual judgment and local experience.

"3. That in making use of the term 'Ore in Sight,' an Engineer should demonstrate that the ore so denominated is capable of being profitably extracted under the working conditions obtaining in the district.

"4. That the members of the Institution be urged to protect the best interests of the profession by using their influence in every way possible to prevent and discourage the use of the term 'Ore in Sight' except as defined above; and the Council also strongly advise that no ambiguity or mystery in this connection should be tolerated, as they (the Council) consider that such ambiguity is an indication of dishonesty or incompetence."

Directors of mining companies are often not acquainted with the principles of mining, and those who are anxious to safeguard their own responsibility, as well as the interests of their shareholders, are obliged to rely upon the mining engineer. We see in practice that this trust can only be reposed on tried men who have gained their confidence, either by having worked for them previously, or else have become such leading lights in our profession that their reports can be implicitly relied upon, in both cases directors are dependant upon the mining engineer, and it therefore behooves every one of us to carefully study and report only facts, and clearly state their reasons when it is a matter of deduction or assumption.

The writer will not expatiate on the pitfalls of the profession. Every one has heard of salting a gold mine, but few perhaps of gilding a salt mine, but this absolutely occurred. An Australian engineer of my acquaintance having been sent on an expedition in the Netherlands East Indies to inspect a property upon which a lode carrying $35 of gold was reported, he returned after a long and trying journey, but his statement was short, merely, "I found no gold, only salt."

THE ATIK-OKAN NICKELIFEROUS PYRRHOTITE DEPOSITS AND THEIR ORIGIN.

By F. Hille, M.E., Port Arthur, Ont.

Introduction.

The Atik-Okan pyrrhotite deposits were discovered in 1882 by an Indian trapper, named "Jim" Shogonosh, who carried the information to a former employer, Mr. G. McClarin, of Savanne. Mr. McClarin, in turn, called the attention of Messrs McKeller Bros., of Fort William, to the discovery, and they applied for, and acquired from the Government what is now known as Locations E. 10 and 11.

From the time of their discovery these deposits have been known as the Atik-Okan "Iron Range." The term, however, is a misnomer, as the deposits do not, in the sense applicable to deposits of pure iron ores found elsewhere, constitute an iron range; and it were equally appropriate to use this designation in describing any deposit where the gossans of a decomposed ferruginous rock, or of iron-bearing minerals, have become changed into iron ore at the surface.

The range consists of a series of gabbro dykes containing pyrrhotite and some magnetite. Such dykes are not an infrequent occurrence in this country; and those near Sudbury, Schreiber, Greenwater Lake, and a number of others in the Thunder Bay District may be instanced.

No detailed reports are available on the Atik-Okan deposits. They have, however, been briefly described by United States' investigators, who signally failed to recognize the true character of the deposits. This failure was not inexcusable considering the rarity of the occurrence, the inconsiderable development work done at the time the examinations were made, and the surface oxidation which might readily admit of misleading conclusions.

General Physical Features.

The name Atik-Okan is derived from the Indian name Aticosepi and means Caribou River; it was given that little stream which has its source in Crooked Pine Lake; a lake of about 10 miles long and from ½ to 2 miles wide, and which flows in a course almost due east and west, forming at certain intervals a number of larger expansions found on the accompanying map and named Magnetic Lake, Whisky Jack Lake and Sabawe Lake. Between the two former the river forms two falls and between the two latter lakes one fall, but neither is more than 10 feet high, and hence incapable of furnishing any considerable power for industrial purposes. Fourteen miles farther west, the Atik-Okan loses its identity by joining its waters with those of the larger Seine River, which forms then a lake-like expansion named Steep Rock Lake

For many years the Atik-Okan, the Seine River and a chain of lakes formed one of the principal canoe-routes into the Rainy Lake and Lake of the Woods regions, but since the Canadian Northern R.R. follows this course very closely the old mode of travelling is now little in vogue.

The whole Atik-Okan country was formerly covered by a dense forest. Even 10 years ago beautiful pine timber could still be seen overgrowing a considerable area, but when nine and seven years ago fires swept that region, it freed it so thoroughly of timber, and even of soil, as to leave the rocks bare, except in some of the lower marshy spots.

The general character of the country north of the river is rugged and broken with a gentle ascent northward. Several chains of hills traverse it in a trend nearly east and west, especially that part between the Atik-Okan and the farther northern Seine River; while south of the Atik-Okan the land slopes gently to the south and southwest forming here a more undulating rocky plain of rough sharp-edged barren rocks. These present features of that region are produced first through erosion and decomposition, and again through the scrubbing action of glaciers of whose movements traces can still be observed at many places in the striæ carved into many different rocks, giving the more basic eruptions a mamillated aspect. These

wandering ice masses formed also the routes for the present water courses and the basins for smaller and larger lakes which can be observed in great numbers in our western country.

The highest elevation is near Magnetic Lake, which is between 1,200 and 1,400 feet above sea level, although the individual hills are seldom more than 150 to 200 feet in height.

It has already been mentioned that the Canadian Northern Railway which, coming from the south-east and striking Crooked Pine Lake between this lake and Elbow Lake, follows the height of land for some distance, reaches the Atik-Okan in the neighborhood of Whisky Jack Lake, and then parallels the waters of this and the Seine River towards Rainy Lake.

Geology.

The rocks which form that region are the following:—Beginning with their enumeration at their geological age, and using the old Canadian classification:

Archæan.

Huronian { Upper: *Keewatin* = Chlorite and hornblende schists and quartz porphyries.
Lower: *Coutchiching*—Fericite schists and evenly foliated grey gneiss.

Laurentian: Biotite granite-gneiss.

Post Archæan.

A granite of greenish aspect, mica changed into chlorite, named Protogine by the author.

Pre-Cambrian.

Dykes of gabbro, and a later muscovite biotite granite in dykes.

The author will abstain here from a minute petrographical description of these rocks occurring at and near the Atik-Okan, and shall only indicate their situation and the relation in which they stand to each other.

Archæan.

(1) Huronian = Upper Huronian: *Keewatin*—Which are represented in the Atik-Okan country first by a narrow band of

chlorite schist which runs out at the west side of Crooked Pine Lake into a number of acicular points curving into a north-eastern direction. North of Sabawe Lake this rock shows a width of only a few hundred yards, but going west it widens out, till it has reached south of Steep Rock Lake a width of about four miles.

To the same series belongs an altered quartz-porphyry which is represented north, south and east of Crooked Pine Lake in some thickness, while north-west of Sabawe Lake in only a narrow stripe which widens out south of Steep Rock Lake.

The schistose structure of these rocks is very marked and all have a strike with the longer diameter. At several places, notably in the neighborhood of Sabawe and Steep Rock Lakes, they show a considerable contortion and shearing.

LOWER HURONIAN—COUTCHICHING.

South of the river another type of rock is met, a sericite schist showing often as an evenly foliated light grey gneissoitic acid rock. It shows a considerable deformation, and at a great number of places is much contorted and twisted, and bleached whitish-grey, an appearance rarely found in the upper Huronian series. It is extremely difficult to state with certainty the original character of these rocks, which have been metamorphosed into something approaching quartz-porphyries, or such rocks as would be produced by an acid magma melting and incorporating into itself portion of the overlying basic rocks. We are perhaps to some extent justified in accepting such a hypothesis, if we consider that in the earlier history of our globe a certain alternation in the production or eruption of acid and basic rock-magmas took place, as we shall see later again to have been the case with the Laurentian, and later series of rocks. Although we cannot shut our eyes to the possibility that this sequence in the production of rocks was in the first period of solid crust-formations, a very slow process on account of the enormous heat which must have existed, it might have happened therefore that long periods intervened between one crust production and the next, and that consequently a lighter acid magma had time to accumulate in greater masses at the surface of the fluid interior, and become then eruptive. As we might conclude from the

Coutchiching to the Laurentian which both were acid magmas, but from that time on we see acid and basic eruptions following each other in regular order.

These Huronian rocks are doubtless the oldest rocks of our earth's crust of which we have knowledge. Whether they constitute the first crust is doubtful, because as these Huronian rocks have been partially remelted, so very likely this may have been the case with earlier crusts as well.*

The schistosity and tilting of these rocks is very likely produced through the contraction of the underlying Laurentian, whose movements they had to follow, and suffer thereby also considerable metamorphism through the heat and consequent chemical changes through thermal mineral waters, etc.

(2) LAURENTIAN.

The next oldest rock of the region is a biotite granite gneiss which covers the largest part of the country surrounding the Huronian everywhere. It has previous to its solidification formed undoubtedly the floor upon which the Huronian has rested, until it became eruptive and remelted the largest portion of the former crust. Of this phenomenon we have ample proof, as a careful field study will soon convince any observer. The papers before mentioned may also be referred to in this connection.

POST-ARCHÆAN—GRANITE.

The next younger rock represented extensively in that region is an altered granite which dates from a time when all Archæan rocks had been produced, but dates also without doubt long before the Cambrian, or, to put it more clearly, became eruptive nearer to the Archæan than the Cambrian period.

This rock has lost wherever it occurs—at least in most places—not its granitic but its through granite aspect, it is no longer greyish or reddish, but has a decided greenish nuance which has been produced through the changing of the mica,

* See Dr. Lawson's report on the Rainy River Region, Can. Geol. Survey Depart. ; and the author's paper on the Animikie Iron Range, Can. Mining Inst. Proceedings for 1903.

and also a part of the feldspar, into a greenish chlorite. For better distinction—principally for the prospectors and miners—the author named it "Protogine" some years ago, by which name it is now usually recognized or distinguished from other granites.

In the reports of the Geological Survey Department we find it described and mapped among the Laurentian as an Hornblende-Granite-Gneiss. This is doubtless erroneous, for if we examine unaltered portions of it, we find that it consists of a true biotite orthoclase granite. The altered portion of the rock on the other hand is seen to consist of quartz, green chloride sericite or muscovite and feldspar, that is, plagioclase and orthoclase, but both have been changed, the latter to a certain extent into sericite and muscovite and the biotite into chlorite here more green, there more whitish or creamy white. Of course the proportion of alteration is not alike in every locality, and it may be that hornblende might have been developed through one or the other process, and there is no doubt that through the intense pressure and shearing which this rock has undergone together with chemical agencies this mineral might have been produced. The chemical changes in the Protogine have been doubtless brought about by the same solutions which produced the fillings of the present gold veins.

On account of the phenomena just described we should have paused and enquired why it is that this granite alone has been selected from all Laurentian granites and gneisses to be changed by crushing and mineral solutions, and why it alone of the whole Laurentian formation contains mineral—here gold veins? It would have been worth the investigation as to whether its origin did not date from a more recent period than the Archæan. A closer field study will convince us that this is so, and we need only examine the contacts between this rock and those of the Laurentian.

But we have now to leave this rock which should interest us more closely on account of the many very good gold veins found therein.

PRE-CAMBRIAN.

(1)—GABBRO.

This rock which follows in chronological order the last

described, is the one which interests us principally here, because it gave origin to this paper.

The reason why it is here classed under "Pre-Cambrian," and not "Post-Huronian" as is often done, is, that this rock appeared long after the deposition of the Animikie and Keneenawan rocks through which it penetrates at many places in the Thunder Bay District, and if we consider that the Animikie rocks were deposited upon the Laurentian granite and gneisses, and were themselves Pre-Cambrian, then it seems justifiable to classify it under that "Inter-period," because it would stand in a nearer chronological sequence to the Cambrian than to the Huronian, that is if we still call Huronian those rocks which we have been for years accustomed to call so, namely Lawson's Keewatin and Coutchiching rocks. This gabbro, as well or better called norite because it is identical with the Sudbury rock now usually given that name, occurs along the Atik-Okan River in a succession of dykes.

The principal mass of this rock is very much altered, and were it not for some apophyses somewhat distinct from the former it would be difficult to collect fresh unaltered specimens by which it would be possible to recognize the true character of the rock. By these samples we can easily distinguish that it consists of orthorombic pyroxene, either hypersthene or enstatite, plagioclase, here and there some quartz magnetic granules and pyrrhotite or pyrite. A considerable portion of the pyroxene is altered into light green and creamy fibrous and scaly masses of serpentine—"Bastite."

The quartz, where observed, is of a glassy, very transparent, or a subtranslucent bluish glassy variety. This quartz is (in the opinion of the author) not a very common occurrence in the Sudbury norite, but it has been noticed in the gabbro of this region very frequently, sometimes in large phenocrysts, accompanying not rarely the massive pyrrhotite.

Pyrrhotite and magnetite are represented in considerable quantity in this rock, the latter mineral unusually so.

We can observe that the rock has suffered a considerable lateral pressure so much so that it has, especially at the surface, the aspect of a ferruginous schist with planes standing almost vertical, this and chemical solutions, and volcanic or meteoric

waters, have been the cause of its considerable metamorphism. The surface of the rock with less magnetite has a greyish green or brownish color, but especially at the farthest eastern outcrop it has a brownish black color produced through the oxidation of the ferro-ferric mineral or iron sulphurets into a hydroferric oxidation product.

Unlike the Sudbury occurrence our pyrrhotite deposits show very little if any chalcopyrite unless perhaps it may be encountered in greater depth (so far the author has not detected it in any of the at least 20 deposits which he has examined in the Thunder Bay District, with the exception of a few small specks in the Atik-Okan deposits which however appear to be of secondary origin.)

Nickel is contained in the Atik-Okan deposits in no small quantity, otherwise we would not find that part dissolved out of the surface ore filling little fissures of the rock in the form of genthite.

The most important exposure of these pyrrhotite-gabbro or norite dykes is east of Tabawe Lake on locations E 10 and 11, which has a length of about 4,000 feet by 288 feet wide at the place of the greatest width, but narrows, east as well as west, into a width of a few inches. Next we come to that on 400-402 west of Tabawe Lake which is of a similar size, but has no longer the same height as the former which is, at the north and south line of E 10 and 11, about 150 feet above the river, nor does it possess the same width, neither does it show the same mineralization at the surface, although the diamond drill proved that the sulphurets are as abundant here as in other places.

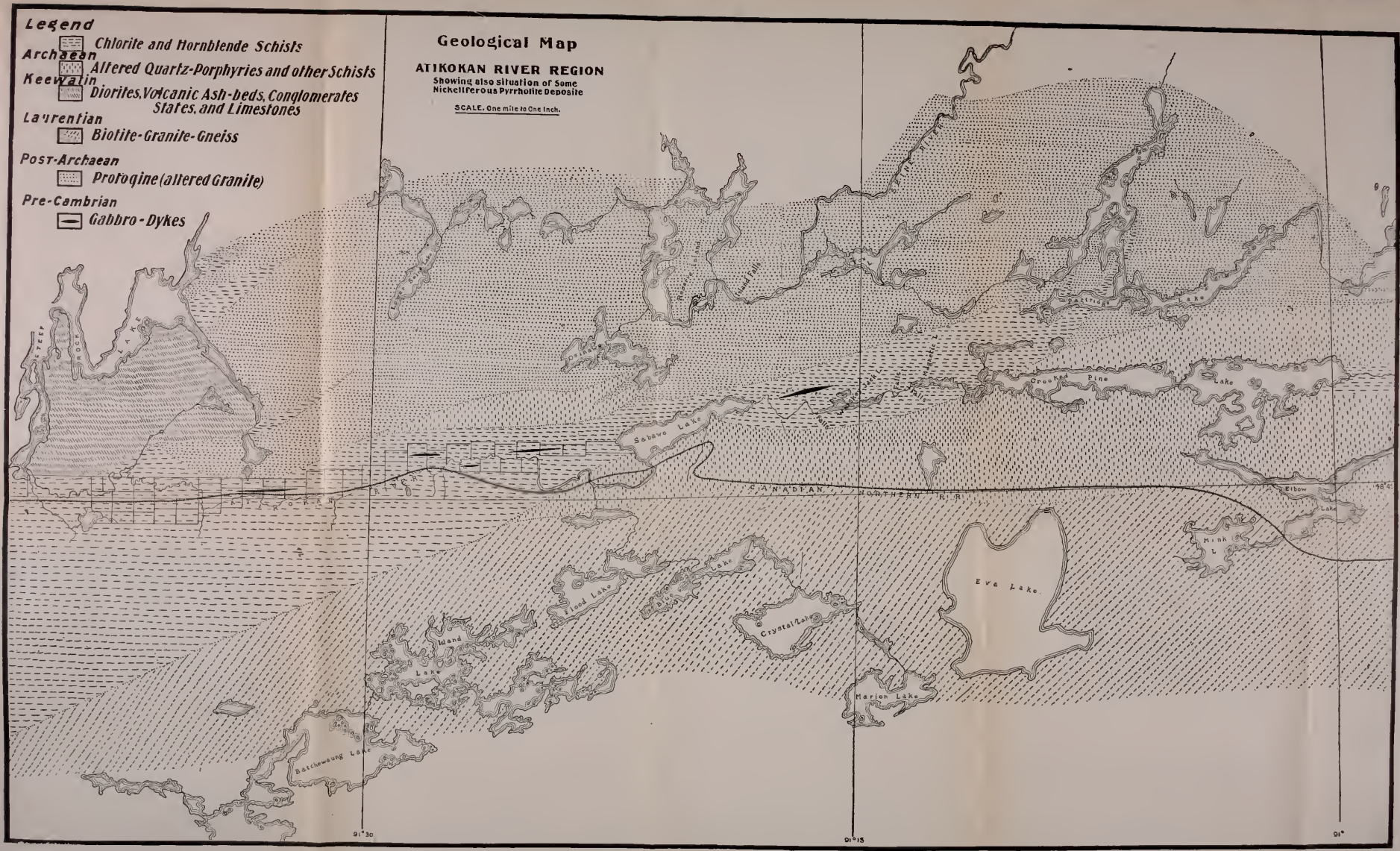
The length of these dyke-outcrops is nearly 12 miles, from Magnetic Lake to south of Steep Rock Lake in an almost east and west line. (See accompanying map.)

It was mentioned above that there are also a number of smaller opophyses of the same rock north of the river, but they are a negligible quantity on account of their insignificant size, being from one to three feet in width.

PRE-CAMBRIAN.

(2)—GRANITE.

There occurs at several places in that region a younger granite, which in a number of instances in both the Thunder


Legend
Archaean
Chlorite and Hornblende Schists
Altered Quartz-Porphyries and other Schists
Keewatin
Diorites, Volcanic Ash-beds, Conglomerates
States, and Limestones
Laurentian
Biotite-Granite-Gneiss
Post-Archaean
Protogine (altered Granite)
Pre-Cambrian
Gabbro-Dykes
Geological Map
ATIKOKAN RIVER REGION
Showing also situation of Some
Nickeliferous Pyrrhotite Deposits
SCALE. One mile to One Inch.
Eye Lake
Partridge Lake
Crooked Pine Lake
Sabaw Lake
Elbow Lake
Mink L.
Eve Lake
Crystal Lake
Fired Lake
Island Lake
Marion Lake
Batchewaung Lake
CANADIAN NORTHERN R.R.
91°30
91°15
91°

Bay and the Rainy River district is very closely associated with the gabbros. This association with Atik-Okan norite can so far not be observed, because not enough work has been done to state positively whether the granite does or does not occur there. There, however, exists a divergence of opinion among a number of observers as to the age of this granite, whether it is the younger or the older, or whether it is the acid facie of the basic gabbro, and differentiates from it by cooling. If we extend our search as to this into other localities, we cannot fail to come to the conclusion that the granite is the younger, and not the gabbro or norite, although we might find instances or conditions which may lead us to believe that the gabbro would be the younger, as it was exemplified with the contact of these rocks at the Copper Cliff Mine No. 2, where the salvage of the norite was said to be finer grained through chilling by the cooler granite. In the author's opinion this might have been the result of a partial remelting of the gabbro contact by the granite, as this is not an infrequent occurrence in the Thunder Bay District, even where at numerous places the granite has incorporated of the gabbro constituents at least 1-5th of its whole mass, forming thereby a very interesting rock of rather mottled appearance. That the granite should have differentiated from the same gabbro magma can easily be disproved by a little closer field-study from which we find that this granite constitutes a much greater volume, *i.e.*, exists in far greater masses than the other rock, and in most cases there is an absolute absence of the latter. There is no doubt that the difference in age of both rocks does not extend over geological periods, but that the granite became eruptive not very long after the consolidation of the gabbro, and that in a number of instances it made use of the contraction space, and of the spaces produced by the shattering of the gabbro to find an outlet upwards. There is also no doubt that the granite magma must have been in a very hot fluid condition, otherwise it would have been hardly possible for it to penetrate in even the very finest cracks and fissures of the gabbro, or would have remelted the gabbro contact, as we can observe repeatedly in both our districts. An attempt is made to illustrate a few such cases. (Fig.4.)

ORIGIN OF THE ATIK-OKAN ORE DEPOSITS.

The author has to repeat here the Atik-Okan ore deposits are a counterpart of the Sudbury nickeliferous pyrrhotite deposits, and if there was an extensive bibliography of the latter ore occurrence he could only point to these. But only those of the Canadian Geological Survey are of value, especially a monograph Part H Annual Report, Vol. XIV, written by Dr. A. E. Barlow, and several papers of Dr. Coleman, Bureau of Mines Report. There are further some papers published on this subject, which lean more to a "neptunic theory," in accordance with the teachings of a certain branch of American geologists, in which at the same time Prof. Vogt's well known hypothesis of differentiation from molten magmas is criticised. I shall abstain from any citation or criticism of the latter, because it is so evident from the study of phenomena of many different ore deposits, and in different localities and regions that Prof. Vogt's hypothesis is absolutely correct, and that in some instances perhaps we have to add one phenomenon or another which has assisted the former in bringing about these results as they are revealed to us now.

When the author visited the Atik-Okan deposits first, which was in the early nineties, he recognized their true nature correctly, and was not mislead by the heavy hydroferric oxide covering, or even by the outcrop of some magnetite lenses. When later repeated diamond drill operations were conducted at them he received the indisputable proof of his determination, which was, "that the rock mass which was standing so prominently over its surroundings was nothing other than gabbro dykes, and that the minerals associated with it, were idiogenetic constituents of the whole dyke—material, separated partly by a differentiation process."*

Dr. Barlow, the author of the monograph mentioned above, recognizes this hypothesis, in describing the Sudbury gabbro or norite masses, as the only one which could be applied to the phenomenon which has caused the pyrrhotite to separate from the rock

* Vide paper on the Iron Ore Deposits of Western Ontario and their Genesis, by the author. C.M.I. Proceedings, Vol. V., page 49.

material. He says *inter alia*: "At the present day fused magmas are regarded as more or less complex solutions, which, by reason of their high temperatures, obey the same laws in the order and method of their solidification as those which govern the crystallization from ordinary solutions of a similar heterogeneous composition." There is no doubt that the constituents of a fused magma will solidify by obeying laws in the same order and method as govern salt solutions in their crystallization. Now to this we have to add: "Should this solidification process not go on in the same order as the different salts are subject to fusion?" With which is meant: "The same degree of heat that is necessary to fuse one salt, is, as soon as it is lowered perceptibly, necessary to begin solidification." Of course it might be possible that the fusion is partly governed, in so great a mixture of different salts, by the influence or action which they exercise upon each other as fluxes. Whether this action has indeed any influence on the solidification of one or the other salt is difficult to state, although it would be hardly necessary to accept, especially in a slow cooling magma.

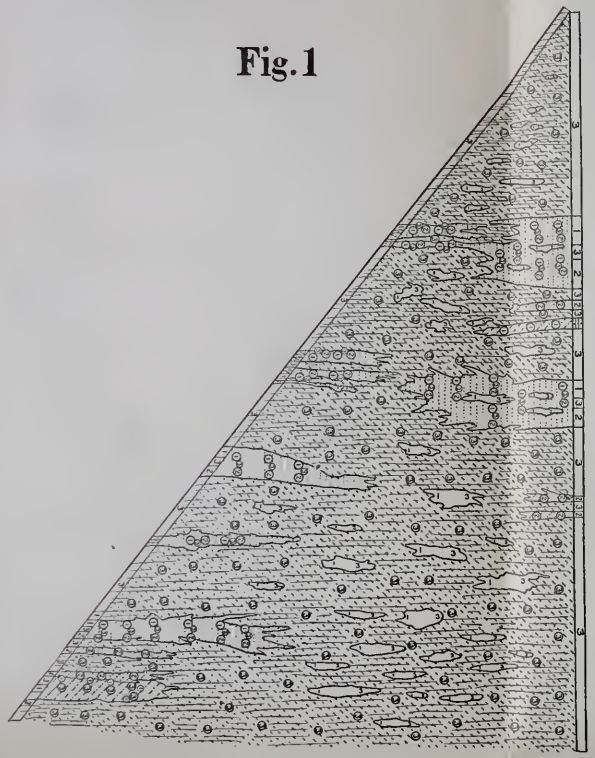
If the above hypothesis is correct, then the claim that in a gabbro or norite magma, the oxides of iron and titanium, the sulphides of iron, nickel, copper and iron and apatite are the first to crystallize, is incorrect. We might prove this with the pyrrhotite, this mineral fuses in a very low heat, how can it crystallize and solidify first in a magma of such intense heat as to retain the ferro-magnesian silicates, olivin, hypersthene, diallage and biotite, still in a liquid form? Let us consider biotite as belonging to the other extreme, this mineral doubtless fuses with great difficulty, and must be one of the first to crystallize out of a still flowing viscous magma, as we can observe in many instances especially in our Laurentian granites in which this mineral arranged itself in certain alignments, giving thereby these rocks a gneisoitic aspect.

Perhaps we might be deceived through the perfect crystallization of the sulphides in the middle of other minerals for which we can account in the following way, that certain portions of the former being surrounded by the latter, first solidifying, and that the crystallization power of these still heated sulphides being stronger, imprest their crystal-forms on the still plastic

rock minerals. Another proof that the sulphides are the last to solidify may be found in the fact, that we find them often in their principal mass accumulated at the outer margin of the rock where they arrived by being pressed outwards towards contraction spaces. Or even that we find them accumulated in larger and smaller lenses in the interior of the rock mass, especially when the latter have been laccolites, as seems the case with the Atik-Okan deposits. Another instance of this is the occurrence of ilmenite in the middle of a gabbro-mass resting "horizontally" therein. It can easily be observed in this case that the gabbro surrounds the ilmenite on all sides. The latter is at its thickest part over 20 feet and is several hundred feet in width, the length cannot be well observed. (Fig. 4.) The author can only explain this phenomenon by suggesting that the weight of the thick viscous rock mass squeezed the still liquid iron-titanium solution into "pools" which collected in the middle of the rock. Three different horizontal layers of this ilmenite have been observed in one dyke.

The author will not say that plutonic solutions, gases and fumes representing the after action of volcanism, has not produced in many instances the deposition of ores, on the contrary, he attributes to these phenomena the existence of most the metallic and their accompanying rock minerals. But it is very questionable whether these pyrrhotites owe their origin to these processes, the less so if they have been laccolites, as which they are spoken of by a number of observers. If these gabbros or norites are laccolites, the position of the pyrrhotite might depend, first, on whether they are injected with great force (and we may expect this in almost every instance) into the outer rock strata; second, on whether they have broken through to the surface and in greater masses. If the first should be the case, then we have to consider the spaces, produced by such force, so completely filled out, and the intruding rock mass itself so much compressed that by cooling it filled out its own contraction space by the relaxation of the pressure. Now, if the second should have happened, then we might consider the possibility that on account of its great volume contraction spaces were formed, and therefore room created for fumarolic activity, and a flow or differentiation of still fluid minerals towards the margin of the gabbro-mass.

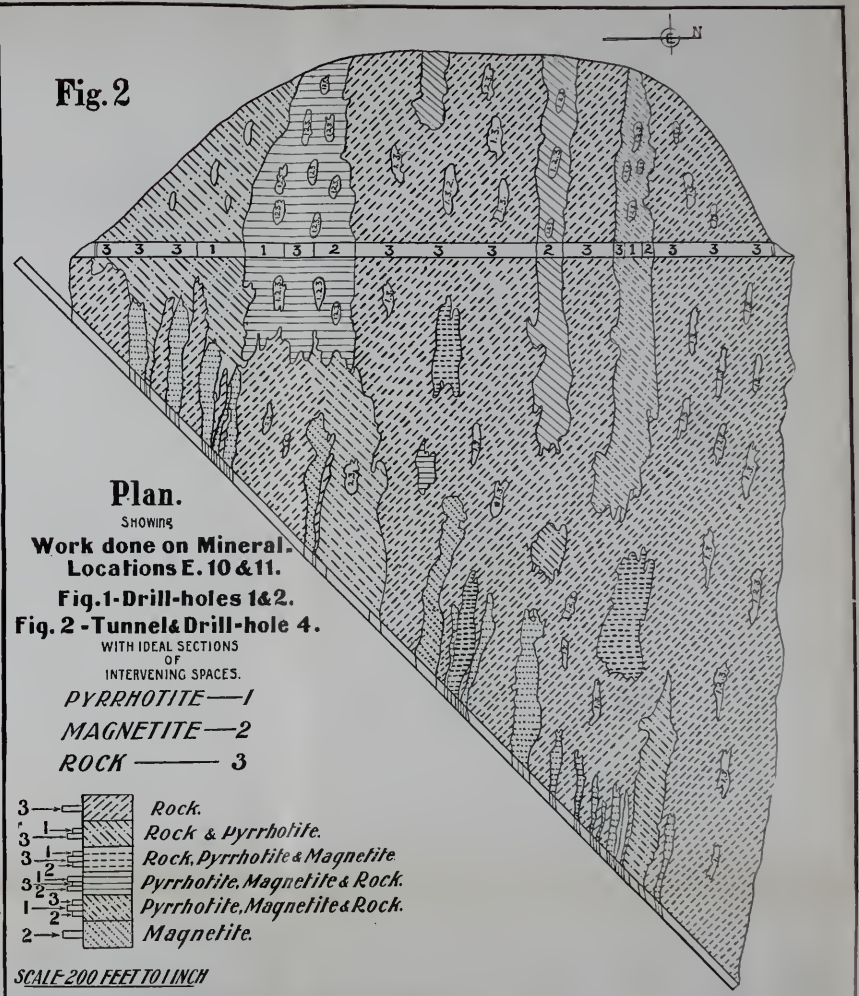
Fig. 1



Total depth of hole 317'10"
Angle 37½°

Total length of hole 260 Feet 5"

Fig. 2



Plan.

SHOWING

Work done on Mineral. Locations E. 10 & 11.

Fig. 1 - Drill-holes 1 & 2.

Fig. 2 - Tunnel & Drill-hole 4.

WITH IDEAL SECTIONS OF INTERVENING SPACES.

PYRRHOTITE — 1

MAGNETITE — 2

ROCK — 3

3 → *Rock.*

3 1 → *Rock & Pyrrhotite.*

3 1 → *Rock, Pyrrhotite & Magnetite*

3 1 2 → *Pyrrhotite, Magnetite & Rock.*

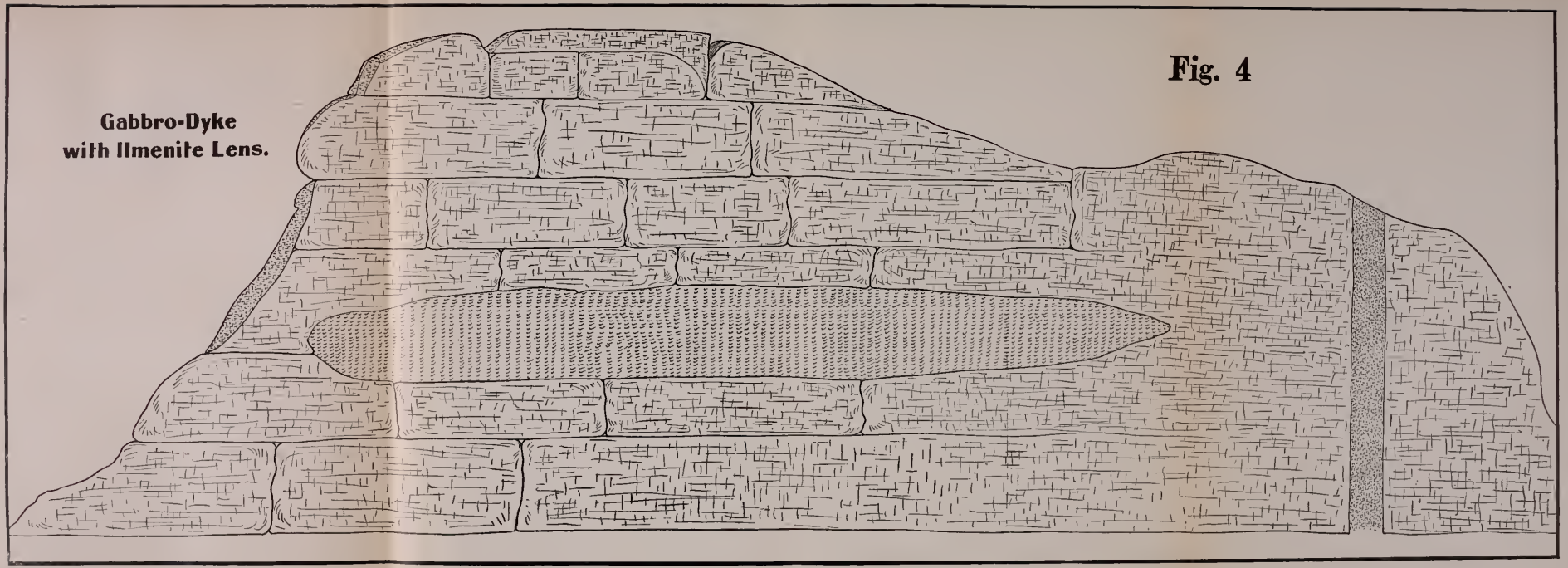
1 3 2 → *Pyrrhotite, Magnetite & Rock.*

2 → *Magnetite.*

SCALE 200 FEET TO 1 INCH

Fig. 4

Gabbro-Dyke
with Ilmenite Lens.



These phenomena might have been the cause of our often finding in the Sudbury district and also in our own region, the pyrrhotite at the margin of the gabbro or norite-masses, and at other places sometimes evenly distributed throughout it, or collected in lenses or nests therein. This latter is precisely what has happened with the Atik-Okan metallic minerals, as the diamond-drill-hole planes accompanying this paper will show (Fig. 1 and 2); it will also be observed therefrom that a good deal of magnetite is mixed with the sulphurets, especially in lense shape accumulations. In the rocky part we find this mineral less represented. A few of these lenses consist almost wholly of magnetite, but they are usually of no great extent in width or depth, of which diamond-drill-hole No. 4, which is put down directly below the tunnel, and hole No. 2 below hole No. 1, will give us proof.

We notice also that a good deal of pyrrhotite is mixed with the rock material, and the fact that the latter is seldom found free of sulphurets might prove that these gabbro or norite dykes contained not only a large percentage of sulphurets and magnetite, but also testifying, through the intimate mixture of their different constituents, as to how they originated and how they cooled. These dykes have suffered a considerable lateral pressure, especially at the north and south side of the dyke, and in consequence have received a schistose structure with planes standing almost vertical. The reason for so much dynamic pressure might be sought in the rocks in which they are imbedded, which very likely had not yet reached their final stage of rest when the gabbro became eruptive, to which it can be added that the following granite might have helped in these movements.

It has been mentioned before that a part of the surface of these dykes was covered with a thick layer of sometimes very pure iron ore, which appeared to be a mixture of a dark brown limonite and magnetite in varying proportions, produced by the decomposition of the sulphurets and the already existing magnetite mixed before with the latter.

Tests made of this material often gave results high in iron, low in silica, low in phosphorus and even in sulphur and nickel. The absence of these elements in harmful or economic quantities might be explained through the leaching process which has been going on for so long a time. The nickel usually accumulated

in the small fissures of the rock as a genthite. The other two elements might also be traced farther downwards if a methodical examination could be pursued, but this would be possible only if regular mining work were going on at these places.

A few tests made of this material in the laboratory of the author show :—

	I.	II.	III.
Iron	62.4%	66.5%	67.2%
Silica	7.1%	3.2%	2.1%
Phosphorus	0.02%	0.015%	0.036%
Sulphur	Trace.	0.01%	0.07%
Nickel	Trace.	Trace.	Trace.
Titanium	Trace.	Trace.	Trace.
Magnesia	0.34%	not det.	not det.
Lime	0.13%	....	....

To which could be added quite a number more, not only made by the author but also by others, but they would not teach more than the above three analyses.

Tests made of seemingly healthy pyrrhotite specimens for nickel gave unsatisfactory results; nothing different was to be expected, as the leaching process of this ore had been going on to considerable depth. This process can be produced artificially in the laboratory. The mode of procedure would have to be as follows:—Place a sound piece of pyrrhotite over an evaporating dish partly filled with water, soon you will observe how the water-vapor commences to disintegrate the specimen, and how the green sulphate of nickel collects at the surface. Bring now water in contact with this salt and it will dissolve. Evaporate the water and a residue of green sulphate of nickel will be found in the dish.

Diamond drill-cores from 200 to 300 feet depth tested for nickel gave from one to two percent of that metal, according to mixture of the sample with rock or magnetite. These tests proved amply that the nickel occurred in the same manner as in the Sudbury deposits.

Copper, usually a companion of the nickel in the latter ores, the author has so far not found in any appreciable quantity here, only traces which seem of secondary origin; whether this

metal will be discovered in greater depth it is difficult to state, at the surface it seems to be absent from nearly all pyrrhotite deposits in this district. The author has tested quite a number of drill-core samples with varying results, according to the part of the core from which they were taken, whether they contained small or larger quantities of rock matter, or whether they consisted of more or less pyrrhotite, or whether the magnetite was the predominating mineral. All these samples contained a certain percentage of nickel, but contained also a much larger percentage of phosphorus than those samples taken from the sur ace.

The percentage of nickel was according to the amount of sulphurets—from 1 to 2%.

The sulphur encountered depended naturally on the proportion of sulphurets to the other constituents. Phosphorus was usually above the Bessemer limit, the average lay near 0.1%; the cause for such a great difference in this element between the ore from the surface and that from 200 to 300 feet depth may be sought in the leaching process, which acted so intensely on the surface ore.

Of titanium the author has discovered only traces.

Calcium, magnesium and aluminium are of course always present.

Considerable prospecting work has been done on some of these dykes, especially on the one east of Sabawe Lake, but those lying west of this lake have been also tested by diamond drill, hand drill and powder. However, the description of this work will be confined to that done on E 10 and 11, known as the McKellar property, which is the more prominent dyke, and has been for years repeatedly before the public as an "Iron Range," as was mentioned at the beginning of this paper.

A description of the work, and the results gained by it, might be also timely at the present moment when an iron company is going to open up the iron deposits there for utilization of the ore in a blast furnace to be built in Port Arthur for the purpose of producing pig iron. This town has given a bonus for the erection of this furnace inside its limits, to the amount of $225,000.

The first work on the above-named locations consisted of a trench cut across the dyke nearly at its widest part. This was done in 1887 for the purpose of finding out whether the

iron ore seen cropping at the surface had width and depth. The results cannot have been so encouraging as a report on this work would indicate, because a deal was not consummated.

In 1900 an irregular tunnel about 5′x6′x288′ long was cut by Mr. Hunter, of Duluth, Minn., through the hill nearly at the same place where the above trench is located, about 100 feet below the top of the hill. Accompanying illustration (Fig 2) will give an idea of what it revealed. A year later the Illinois Steel Co. put a number of diamond drill holes in the same dyke to verify the existence of iron ore. Fig. 1 and 2 are the plans of three out of four holes. No business transaction took place after that, perhaps for the reason I mentioned above, viz., that the ore was found to be of non-Bessemer-grade towards depth.

For instance, the average of a number of samples taken from the tunnel where the best ore occurred, gave:—

	One Lot.	*Another Lot.*
Iron	58.16%	59.03%
Phosphorus	0.078%	0.093%
Sulphur	1.90%	0.58%

FROM DRILL HOLES, BEST ORE TAKEN

	Average of Seven Samples.	Average of another lot.
Iron	59.30%	59.68%
Phosphorus	0.069%	0.054%
Sulphur	1.090%	1.91%

These tests show, compared with those made of surface ore, quite different results, the ore having changed from a Bessemer into a non-Bessemer.

Now, as regards the extent of these ore bodies, we need only examine drill holes 1 and 3, and further the tunnel and drill hole No. 4 (the latter holes are one directly below drill hole No. 1, and the other below the tunnel), and observe that there exists no continuity downwards, but that the ore appears sometimes as larger, sometimes as smaller lenses, and in a mixture in which first one mineral, then the other predominates. This is indicated with colors on the accompanying plans.

Further we notice that the walls of the dyke consist principally of rock material, and not, as is the case in many similar pyrrhotite deposits, of accumulations of sulphides; we can explain this only in the way suggested above. Last spring and summer some more diamond drilling was done on the same dyke, but detailed actual results are not at hand. Trustworthy sources, however, affirmed that the results had not turned out differently from those of the earlier test work. This cannot be doubted, as the author has seen all the drill cores coming from the different locations along the Atik-Okan, and they are all alike. It is very doubtful whether it is rational to mine these scattered lenses of pyrrhotite and magnetite and prepare these ores for smelting in a blast furnace for making a non-Bessemer pig iron out of it.

ON THE NICKEL DEPOSITS OF WEBSTER, WESTERN NORTH CAROLINA.

By Alfred E. Barlow, D. Sc.

(By permission of the Director, Geological Survey of Canada).

Introduction.

The main thoroughfare of the town of Webster, the capital of Jackson county in western North Carolina, runs northeast and southwest, over the broad rounded summit of a comparatively low mountain. This hill—for it can scarcely be dignified by the name of mountain—is terminated on the west by a sharp bend to the north of the Tuckaseegee river (a branch of the Tennessee river), while to the east it is interrupted by the valley of Fisher creek, a small tributary which enters the main stream from the northeast. The nearest railway station is Dillsboro, on the Asheville-Murphy division of the Southern railway, 48.9 miles southwest of Asheville. A waggon road connects Dillsboro and Webster, the distance being about three and a half miles. This road runs along the northeast bank of the Tuckaseegee, following very closely the several bends of the stream in this distance. As a consequence, it presents an easy upgrade until the immediate vicinity of Webster is reached, when a climb of nearly two hundred feet is necessary to arrive at the top of the hill upon which the town is built. If desirable, a tramway or railway could be constructed from Dillsboro to Webster, following the river all the way, for the level of the railway at Dillsboro is 2,006 feet above sea level, while the altitude of the bridge crossing the Tuckaseegee river, southwest of Webster, is only 38 feet higher. Communication with Webster is also sometimes made by way of Sylva, the next station northeast of Dillsboro, the waggon

road passing on the opposite or northeast side of Kings mountain, and reaching Webster from the northeast. The distance by this route, however, is a little longer, or about four miles.

Much of the area in the immediate vicinity of Webster, as shown on the accompanying map, is underlaid by the peculiar and characteristic basic magnesian rocks, containing the nickel deposits which are the subject of the present description. The rocks belong to the peridotite family, represented mainly by the two rock species known as dunite and websterite, and certain altered derivatives. They have apparently offered a comparatively feeble resistance to the long continued processes of atmospheric decay, and, as a consequence, now present a series of relatively low, rounded hills, separated by shallow and gently sloping valleys. These hills have an altitude of from 2,100 to 2,400 feet above the sea, while in the area immediately adjacent, but a little more remote from Webster, which is underlaid by the harder and more unyielding Archaean gneisses, the mountains are much more rugged, rising to a height of from 3,000 to 4,000 feet above the sea.

HISTORICAL.

The occurrence of nickel at Webster has been known to mineralogists and geologists for many years, and as far back as the year 1872 a detailed analysis of the nickel bearing mineral was published by Dunnington, showing it to be a hydrous silicate of magnesium and nickel. (1). It was not, however, until the year 1886 that public attention was directed to the economic possibilities of these deposits and their probable importance as a large producer of nickel. In this year the first attempts were made to develop these properties, in order to arrive at a just appreciation of their richness and extent. At the same time Mr. Henry J. Biddle was sent, at the instance of the United States Geological Survey, with instructions to make a careful and detailed examination, and his report, published soon after

(1). Chemical News, Vol. XXV, 1872, p. 270.

was the first comprehensive and authoritative statement in regard to these occurrences. (1).

In 1887 Col. W. B. Robison, of Murfreesboro, Tenn., and Mr. A. B. Travel, of Nashville, Tenn., purchased the mineral rights in the "Love Tract" of about 100 acres on the north side of the Tuckaseegee river, while Captain C. C. Pinckney and his partner and agent, Major E. Willis, both of Charleston, S.C., purchased similar rights in the "Monteith and Fullbright Tracts," comprising between 500 and 600 acres on the south side of the river. Both parties immediately began to test their properties, mainly by means of trenches, pits and shallow shafts. Many of these were only sunk to the level of the solid rock, and the information thus gained was entirely inadequate to enable a true judgment to be formed of the real value of these deposits.

In 1888 a small shipment of nickel ore was made to New York, but no further development work was undertaken.

In 1891, it is stated by the United States Geological Survey, that "prospecting has continued at the silicate mines near Webster, N.C., without any such decisive results as the production of ore for sale."

In 1892, Dr. Stephen H. Emmens, of the Emmens Metal Company of Youngwood, Penna., published a description of these deposits, in which he summarizes his observations as follows:— 1. There does not exist any deposit of *proved value.* 2. The chrysolite rocks in the neighborhood of Webster are, undoubtedly, nickeliferous in a commercial sense of the term. 3. It is probable that judicious exploration will open up deposits of limited extent but capable of being profitably worked for some years. (2).

During 1902 and 1903, additional and much more extensive development work was undertaken. This consisted, in the main, of a series of parallel trenches which were excavated, in some cases, simply to the solid rock beneath, and in others to a uniform depth in no case exceeding about 30 feet. These ditches were opened up approximately parallel to one another, with a general direction of N. 87° W. (Mag.), or across the peridotite band. At one place a trench was run almost at right

(1). Min. Res. U.S., 1886, pp. 170-171.

(2). Eng. and Min. Jour., Vol. LIII, 1892, pp. 476-477.

angles to these, or in a direction of N.6°W. (Mag.). By means of these trenches it was possible to obtain not only a more accurate appreciation of the quantity of ore which would be available for shipment but also to study the mode of occurrence of these deposits. Diamond drilling was also undertaken to determine definitely whether the silicate veins continued into the undecomposed peridotite. Several car-loads of ore were secured by this development work, and this was shipped to New York where experiments were conducted to determine the most suitable method of treatment for the extraction of the nickel.

CHARACTER AND COMPOSITION OF THE ORE.

The nickel-bearing mineral occurring at Webster is a hydrous silicate of magnesium and nickel, very closely allied in chemical composition to the noumeaite and garnierite of the celebrated New Caledonia nickel mines.

Such a combination was first described by Dr. F. A. Genth in 1851, under the name of "Nickel-Gymnite," the material on which his determination was based occurring in thin crusts on chromite in Lancaster county, Pennsylvania. (1). In 1854, Dr. T. Sterry Hunt described a closely related mineral from Michipicoten island, in Lake Superior, where it "occurs as a gangue of native copper and native silver, which are disseminated through it in grains." (2).

In 1867 Dana proposed the general name of "Genthite" for these and other closely related species. Under this name, therefore, may be included Garnierite and Noumeaite (or Noumeite), Pimelite, Alipite, Refdanskite (or Rewdinskite) and Röttisite.

The mineral is amorphous, filling certain cracks with encrusting, delicate, hemispherical or stalactitic forms; usually soft and friable; falling to pieces in water; unctuous to the touch and adhering slightly to the tongue. The lustre is dull or resinous. It varies in colour from pale yellowish green to deep green, and it is the prevailing rule that depth of colour accompanies an increase in the nickel contents. The specific gravity varies in

(1). Keller and Tiedemann's Monatsbericht, Vol. III, 1851, p. 487.

(2). Ann. Rep. Geol. Surv. Can., 1853-56, pp. 389-390: also Geology of Canada, 1863, pp. 506-507.

general from 2.25 to 2.50. The hardness also varies generally from 3 to 4, although the mineral is sometimes so soft as to be polished under the nail. These hydrous silicates of nickel and magnesium have been described from a number of localities in the world, but with the exception of the New Caledonia occurrences they have not been of sufficient extent to be economically valuable.

ANALYSES OF NICKEL-MAGNESIUM-SILICATES.

	Silica	Nickel oxide	Magnesia	Water	Alumina	Iron Oxide		Lime	Total
						Fe_2O_3	FeO		
1	49.89	16.60	22.35	12.36			0.06		101.26
2	55.38	17.84	15.62	10.77		0.56			100.17
3	44.73	25.57	10.56	15.86		1.18			99.90
4	48.21	23.88	19.90	6.63		1.38			100.00
5	40.55	29.66	21.70	7.00		1.33			100.24
6	35.36	30.64	14.60	19.09			0.24	0.26	100.19
7	33.60	30.40	3.55	17.10	8.40		2.25	4.09	99.39
8	35.45	45.15	2.47	15.55		0.50			99.12
9	44.40	38.61	3.45	10.34		1.68	0.43	1.07	99.98
10	38.35	32.52	10.61	17.97		0.55			100.00
11	37.49	29.72	14.97	17.60		0.11			99.89
12	47.90	24.00	12.51	12.73		3.00		trace	100.14
13	48.25	14.60	16.40	19.77		0.55			99.57
14	50.15	10.20	17.43	21.65		0.57			100.00
15	51.94	2.32	21.35	23.17		1.36			100.14
16	53.80	0.24	24.82	21.47					100.33
17	41.80	.....	37.38	20.39		1.26			100.83
18	35.00	15.63	1.25	38.12	5.00	4.58		0.42	100.00
19	35.80	2.78	14.66	21.03	23.04	2.69			100.00
20	54.63	32.66	5.89	5.23	0.30		1.13	0.16 (sand)	100.00
21	32.10	18.33	11.50	9.50	3.25		2.15	13.00	99.83

1. Genthite, Webster, N.C. (Dunnington, Ch. News XXV. 270. 1872).
2. Sepiolite, ,, ,, ,, (P. H. Walker, Am. Ch. J. X. 44, 1888).
3. Genthite, Riddles, Oregon. (F. W. Clarke, Am. Jour. Sc. XXXV. 483, 1888).
4. Genthite, Riddles, Oregon. (Hood, Min. Res. U.S. I., 404, 1883).
5. Genthite, Riddles, Oregon. (Hood, Min. Res. U.S. I., 404, 1883).
6. Genthite, Texas, Penna. (Genth, Kell & Tiedm. Monatsb. III., 487, 1851).
7. Genthite, Michipicoten Id. Canada (Hunt., Ann. Rep. Geol. Surv. Can., 1853-56, p. 389).
8. Genthite, New Caledonia (Dann?, Ber. Nied. Gest. Janv. 7th, 1878).
9. Genthite, New Caledonia (Garnier, Comptes Rendus LXXXVI. 684, 1878).
10. Noumeaite, (dark green), Nakety, N. Caledonia (Liversidge Minerals N. S. W., 278, 1888.
11. Noumeaite, (lighter green), Boa Kaine Mine, Kanala, N. Caledonia (Liversidge Min. N. S. W. 278, 1888).

12. Noumeaite, New Caledonia, (Liversidge, Proc. Roy. Soc. N. S. W. Dec. 9, 1874).
13. Noumeaite, (light green), Bel Air Mine Ouaïlou, (Liversidge, Min. N. S. W. 277, 1888).
14. Noumeaite, (pale green), Bel Air Mine Ouaïlou, (Liversidge, Min. N.S. W. 277, 1888).
15. Noumeaite, (very pale green), Bel Air Mine, Kanala (Liversidge Min. N.S. W. 279, 1888).
16. Noumeaite, (no green tinge), Bel Air Mine, Kanala (Liversidge Min. N. S W. 279, 1888).
17. White veins in green mineral resembling sepiolite, (Garnier C. R. LXXXVI. 684, 1878).
18. Chrysoprase earth, Silesia, (Klaproth, Handb. d. Mineral Chemie 871, 1860.)
19. Pimelite (W. Baer, Journal de Physique. LV. 49. 1852.
20. Alipite (Schmidt, Ann. d. Phys. und Chemie, Vol. LXI. 405, 1861.
21. Rewdinskite, Urals, (Hermann, Jour. Prak. Chemie CII. 405, 1867).

EXPLANATIONS.

The analyses quoted above will serve to show at once that the Webster nickel mineral (analyses 1 and 2) is very closely related to, if not identical with, other compounds found under practically the same conditions in other parts of the world. The list has been made rather complete so as to exhibit in a very striking manner, the extreme variability in composition of these nickel compounds, ranging as they do from practically pure hydrous silicates of nickel, as shown in the analyses included under 8 and 9, to what is, on the other hand, almost pure hydrous silicates of magnesia as under 16 and 17.

The analyses of the Webster nickel mineral quoted above under 1 and 2 were doubtless conducted on material which had been selected with the greatest care. No such rich ore was collected by the writer during his visit to the locality to examine these deposits.

From the material then secured four samples were chosen as representatives of the purer varieties of this nickel ore. These were submitted to Prof. J. T. Donald, of Montreal, for assay, with the following results:—

A. Bright apple green material, occurring in small compact veins, traversing the decomposed dunite. The sample was selected as free from impurities as possible. It contained 5.82 per cent. of metallic nickel.

B. Pale green, friable silicate, apparently free from impurity —contained 6.07 per cent. of nickel.

C. Pale green silicate ore with abundantly disseminate minute scales of chrome mica—as free from admixture as possible —contained 6.19 per cent. of nickel.

D. Decomposed dunite, with much intermixed silicate material—contained 5.32 per cent of nickel.

Professor Donald also mentions that there is a certain amount of chromite in some of these samples, No. 4 containing a large percentage. If there is any cobalt present it is included in the nickel, as no attempt at a separation was made.

Thomas Jenkins, the resident chemist employed by the mine owners in 1903, found a specimen very similar to No. 3 to contain 7.32 per cent. of nickel oxide, while his analyses of portions of the decomposed dunite showed it to contain 1.53 to 1.73 per cent. of nickel oxide. (1).

Mr. C. T. Mixer, the chemist of the Emmens Metal company at Youngwood, Pa., made an assay of a sample of this ore, carefully selected by Dr. Emmens, and found it to contain 19.50 per cent. (dry weight) of metallic nickel, while another specimen, which seemed almost as rich judging by the depth of the green colour but containing many scales of vermiculite gave only 2 per cent. of nickel. In the same article Dr. Emmens states that he "engaged a force of ten local miners and instructed them to 'pick the eyes,' as the Cornish miners say, of the rich deposits said to have been discovered. The men did their utmost and worked vigorously at the various show places. In some three days they had practically exhausted the ore in sight, and had obtained 14 sacks of very wet mineral. This, when analyzed by Mr. Mixer, showed 6.1 per cent. of nickel in 50 lbs. of selected ore and 3.6 per cent. in the remaining 700 lbs." (2).

The statement may be made without fear of contradiction that so far we have failed to secure any mineral specimens from Webster which are as rich in nickel as those from New Caledonia represented by analyses 8-12, both inclusive. It is also equally true that the nickel ore of Webster is, in general, much lower in grade than that from New Caledonia. All of the New Caledonia ores contain a little cobalt oxide, seldom over 0.06 per cent. For

(1). Nickel oxide contains 78.5 per cent. of metallic nickel.

(2). Eng. & Min. Jour. Vol. LIII, 1892, p. 477.

purposes of commerce it has been customary to mix the poorer and richer grades together and thus obtain a more uniform grade for shipment. On an average the ore shipped within the last few years from New Caledonia would contain as follows, although each succeeding year sees a poorer product shipped:

Nickel oxide	9-17	per cent.
Silica	41-46	,,
Iron Oxide	5-14	,,
Alumina	1-7	,,
Magnesia	6-9	,,
Water	8-16	,,

GEOLOGICAL RELATIONS.

These hydrous silicates of nickel and magnesium, constituting the Webster ore bodies, occur in the form of irregular secondary veins which traverse an intrusive mass of non-feldspathic basic magnesian rock of prevalent peridotite facies. As will be more fully explained later these veins are the direct product of the leaching of the peridotite by ordinary processes of subaerial decay. In point of shape the Webster peridotite shows no resemblance whatever to the lenticular outline which is almost everywhere characteristic of areas of similar rocks, which occur throughout the entire length of the eastern crystalline belt from Newfoundland and Quebec to central Alabama.

The general line of outcrop of this apparently unique mass forms "an almost unbroken ellipse, mostly northeast of Webster, with a major axis of six miles lying in a direction N. 23° E., and a minor axis of three and a half miles. The width of exposure varies from a third of a mile at Webster, to extremely attenuated strips of talc (altered peridotite) in several places; and on the eastern side five breaks occur, the smaller disconnected masses having typical lenticular form." (1).

The nickel occurrences which are the subject of the present description occur in connection with the broadest portion of this band, in the immediate vicinity of Webster. This part of the ellipse, which mainly by reason of its superior dimensions and richness has attracted the attention of mining men, may perhaps

(1). Lewis, "Corundum and the Basic Magnesian Rocks of Western North Carolina" Bull. 11, N.C. Geol. Surv. 1896, pp. 37-38.

be best described as forming a curving lens-shaped mass with the convex side toward the town of Webster. At the north end, the outcrops of peridotite are distinctly laminated, presenting a parallel series of planes which have a rather uniform direction of N.2°E. (Mag.) with a dip to the west at angles of from 75° to 85°. This strike gradually changes to the southeast in going south on the exposures, and a mean of several strikes gave a direction of S.35°E. (Mag.) with a westerly dip at high angles. This foliated structure is only characteristic of the narrow portions of the band, or of the area in the vicinity of the line of junction with the gneissic rocks. Towards the centre the rock is much more massive, with a jointed structure, one set of well marked planes showing a westerly inclination at an angle of 20°.

The gneisses through which the peridotite is believed to have been intruded, appear, from a rather hasty examination, to be, for the most part, deformed granites and diorites usually classified and described as of Laurentian or Archaean age. One type, collected from near the crossing of the Tuckaseegee river, proved to be a highly garnetiferous hornblende-granite-gneiss. In certain localities, as in the vicinity of Savannah, near the Georgia boundary line, there are outcrops of sillimanite-gneiss, with abundant sulphides, chiefly pyrrhotite and chalcopyrite Similar gneisses have been very fully described by Dr. F. D. Adams from the Grenville series of Canada (1) and are regarded by him as of distinctly sedimentary origin.

Regarding the age of this peridotite, the conclusions of Messrs. Pratt and Lewis, who have examined the area in much detail, may be summarized as follows:—(2).

"Sufficient data are not yet available for a satisfactory determination of the age of these rocks, but their intrusion was probably contemporaneous, or practically so, for the whole region from Newfoundland to Alabama. The peridotite belt lies in a region of great disturbance and intense metamorphism. This fact, together with the geological relations to the northward, suggests the hypothesis that the principal period of intrusion

(1). Ann. Rep. Geol. Surv. Can., Vol. VIII, 1895, Part J. pp. 49-61.

(2). Jour., Elisha Mitchell Scien. Soc., Vol. XXII No. 1,March, 1906, pp. 11 and 12; also "Corundum and the Peridotites of Western North Carolina, Reps. N. C. Geol. Surv. Vol. I, Chapel Hill, N.C.

was closely associated with the orogenic movements which closed the Lower Silurian (Ordovician) period. The distribution of these rocks may well mark to a great extent the axis of most intense folding and faulting. The latter Appalachian disturbances, at the close of the Carboniferous, have produced the laminations so often seen in these rocks and have probably given occasion for later minor intrusions. This hypothesis is not offered as a final answer to the question of age of the peridotites. Much painstaking work yet remains to be done before an entirely satisfactory solution of this problem can be expected."

The Webster peridotite is represented by two distinctly separable, although closely related, rock species known to geologists and petrographers as dunite and websterite. So far as observed, however, there is no gradual transition from one to the other; the two types remain quite distinct. The Websterite has only been recognized at the type locality near Webster and on Cane creek, about six miles farther east. Near Webster it occupies an area within the dunite about a mile in length and nearly 300 feet in width. It closely resembles the dunite with which it is associated, although it is more massive in character, has a more brilliant deep colour and is less altered on the surface. It is also quite prominent in the field owing to the vigorous vegetation it supports in contrast with the barren dunite.

Websterite was first described and named by the late Prof. G. H. Williams, from species collected at Webster. The following is his description:—(1). "The base of this rock is a saccharoidal and easily pulverent aggregate of bright green diopside through which are distributed large and somewhat rounded crystals of a pale brown bronzite, whose diameter is from one to three millimeters. The relative amount of bronzite is quite variable even in the same hand specimen, showing a tendency to concentration in nests or bands, but the porphyritic structure of the rock is, nevertheless, very pronounced, and there can be no doubt that the bronzite is decidedly the older of the two constituents."

Dunite was first described by von Hochstetter in 1864, the original locality being Dun mountain in New Zealand. (2).

(1). Am. Geol. Vol. VI, 1890, pp. 43-44.
(2). Geol. V. Neuseeland, 1864, p. 218; also Z. d. d. g. G., 1864, p. 341.

The dull brown colour of the bare, weathered surfaces of this rock gave the name to the mountain and thus to the rock itself. The rock as originally discovered and described was found to consist almost entirely of granular olivine with chromite or picotite in small octahedral crystals scattered throughout the mass. The Webster dunite is almost identical with that from the type locality in New Zealand. The thin sections show a rock made up almost exclusively of olivine with small octahedra or rounded grains of chromite or picotite disseminated throughout. Sometimes the chromite becomes more abundant and is seggregated together in irregular masses, which occasionally attain such dimensions as to become economically valuable as an ore of chromium. The various stages in the serpentinization of the olivine may, no doubt, be studied by means of thin sections made from these exposures, but in none of the slides examined was this process very far advanced.

The following will show the chemical composition of the Webster peridotite:—

Analyses of Webster Peridotite.

	I.	II.	III.
SiO_2	41.89	40.74	55.14
TiO_2	..	..	trace
Al_2O_3	trace	trace	0.66
Cr_2O_3	0.58	1.83	0.25
Fe_2O_3	..	..	3.48
FeO	7.39	7.26	4.73
MnO	..	..	0.03
NiO	0.35	0.39	0.11
CaO	0.06	0.02	8.39
MgO	49.13	49.18	26.66
K_2O	..	..	undet.
Na_2O	..	..	0.30
H_2O	0.82	0.76	0.38
P_2O_5	..	..	0.23
Total	100.22	100.18	100.36

I. and II. are analyses of the Webster dunite by F. A. Genth (Bull. U.S. Geol. Surv. No. 74, 1891, p. 47). III. Analysis of Webster websterite by E. A. Schneider (Am. Geol. vol. vi, p. 44; also Bull's U.S. Geol. Surv., No. 148, p. 92, and No. 168, p. 53).

Mode of Occurrence.

In the final weathering and degradation of the peridotite, most, if not all, of the nickel originally present in the unaltered rock is leached out to be concentrated in certain irregular cracks

and fissures a few feet lower down. The ore rarely, if ever, crops out at the surface, which, for the most part, is covered with a thick mantle of decomposed material. This covering or soil is very highly ferruginous, being largely composed of pisolitic iron ore (limonite), with occasional large "chert" fragments scattered about. These pseudo-boulders or fragments of so-called chert, many of which are being brought to the surface by the action of the frost, really represent portions of the peridotite which have escaped the wholesale disintegration by reason of their being held together by an intricate series of quartz veinlets, the interstices of which are occupied by only partially decomposed peridotite. They are considered a very favourable sign in prospecting for the ore bodies, as they indicate the presence beneath of the nickeliferous peridotite. The surface mantle or soil varies from almost nothing up to a few feet when it gives place gradually to a loose brownish material representing the decomposition "in situ" of the peridotite. This usually shows abundant but small and intricate veins of the greenish silicate of nickel and magnesium, often with numerous small scales of chromiferous mica. In places irregular veins, occasionally of considerable size—from 2 to even 4 feet in width,—are occupied by comparatively pure silicates, but as a rule the veins or concentrations are much smaller. This brownish loose material gives place in turn to a deep brown, soft, friable rock, filled with much smaller but harder and richer veinlets of nickel silicates, while this again is replaced gradually by the unaltered peridotite which contains little, or none, of the silicate material.

ORIGIN.

The presence of nickel as an essential, although for the most part unimportant, constituent of certain basic igneous rocks belonging mainly to the peridotite family, is a fact which has frequently been noticed and commented upon in the various descriptions of natural occurrences of this element. Most of such occurrences of nickel are, however, of scientific interest only, as the metal, in this particular, is so uniformly distributed throughout the whole rock mass that its presence is entirely unsuspected by ordinary observers, while its proportion is so

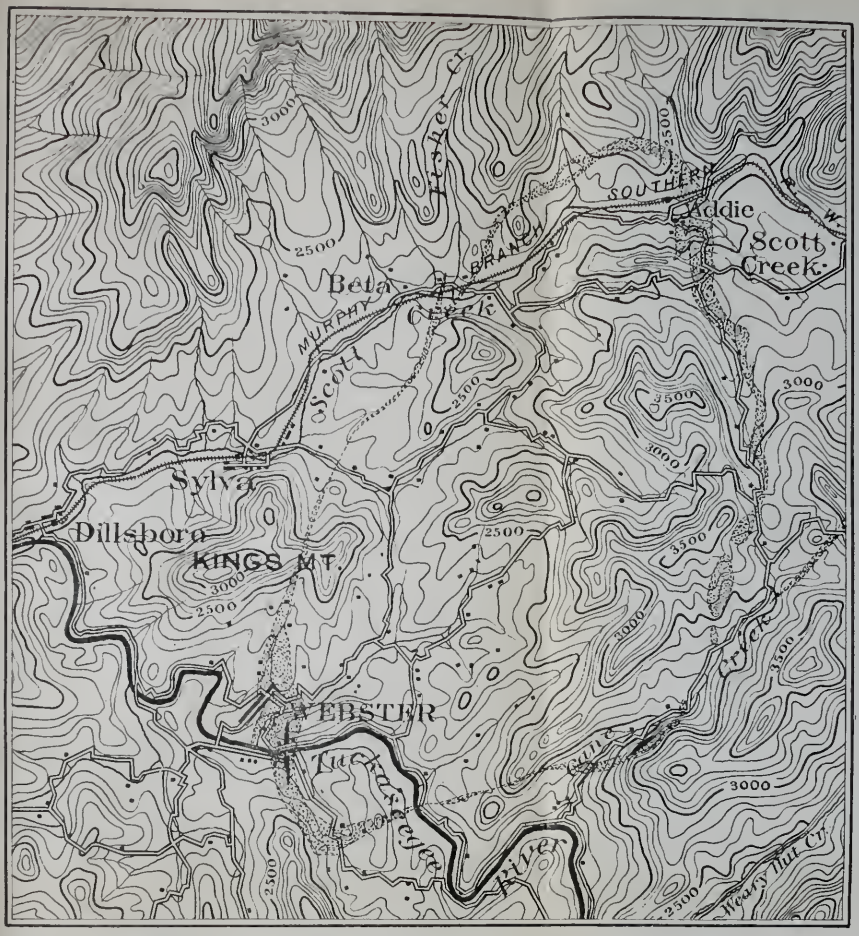
small that much care and skill are necessary for its determination even by the ordinary methods of chemical analysis. This is especially noteworthy of occurrences of these basic magnesian rocks situated in more northerly latitudes, from which all surface decomposition products have been removed by glacial action, leaving exposed at the surface the hard and comparatively unaltered rock. In unglaciated districts, however, such as those of North Carolina, the conditions are entirely different, and most of the underlying rocks, especially on the hillsides and valleys are covered by a thick mantle of decomposition products, the accumulation of untold centuries of subaerial decay. This greatly prolonged period of weathering was necessarily favourable to the leaching out of the nickel from the enclosing rock, and its redeposition in conjunction with the silica and magnesia at various depths below. From analyses of the peridotite obtained in the vicinity of Webster, it would appear that the unaltered rock contains from 0.11 to 0.39 per cent. of nickel oxide, with minute traces of cobalt (see analyses above). The saxonite (a closely related rock) from Riddle's in Douglas county, Oregon, from which the nickel silicates at this locality have been derived, contains 0.10 per cent. of nickel oxide, while the olivine itself, of which the rock is mainly composed, contains as high as 0.26 per cent. of nickel oxide. This is a very usual association for such rock, for the undecomposed peridotite (or serpentine) of New Caledonia contains as high as 1 per cent. of nickel oxide.

Similar rocks from the Eastern Townships of Canada show the presence of 0.15 to 0.26 per cent. of oxide of nickel, without cobalt, and the associated chromic iron ore also contains 0.22 per cent. of nickel with distinct traces of cobalt. (1). It has been stated, and is no doubt true, that it is almost impossible to collect any material resulting from the decomposition of the Webster peridotite without finding an appreciable quantity of nickel present. It appears, therefore, that the nickel has been leached out of the peridotite and redeposited with silica and magnesia in all available cracks and fissures. The peridotite is decomposed under ordinary conditions of atmospheric decay, the magnesia being the first ingredient to be carried away in the

(1). Ann. Rep. Geol. Surv. Can., 1853-56, pp. 434-436 also pp. 444-447; also Geology of Canada, 1863, p. 507.

form of a carbonate. This is followed by the silica and nickel, which is redeposited at lower levels and in suitable places. Without consideration, therefore, of the surface soil from which most of the nickel has been removed, the higher portions of the deposits are likely, on the whole, to be richer than those lower down.

The result of such an origin will be the occurrence, at this place, of comparatively shallow deposits, varying from almost nothing up to 30, or in places to even 50 feet, depending entirely on the depth to which decomposition has proceeded. It is not possible to ship, or utilize for purposes of refining, the whole of the material exposed by the trenches, but the development should have enabled a very close estimate to be formed of what proportion of merchantable ore could be economically secured. It is certain that the expense of considerable dead work can be borne in order to secure comparatively rich ore, although in so doing a large amount of material will have to be rejected. In the present state of the nickel market, with the large supplies which are assured by the deposits of Sudbury and New Caledonia, it is unlikely that these deposits will receive more than passing attention.



LEGEND

Dunite

Websterite } Nickel-Bearing Eruptive

Archaean Gneiss

— MAP OF THE —

NICKEL-BEARING AREA

IN THE VICINITY

OF

WEBSTER

JACKSON COUNTY, N. C.

After J. Volney Lewis.

SCALE

0 ½ 1 2 3 Miles

NOTES ON DIAMOND DRILLING IN THE BOUNDARY DISTRICT.

By Frederic Keffer, Greenwood, B.C.

As an adjunct in prospecting and developing the low grade ore deposits of the Boundary, the diamond drill has proved an unqualified success. As these great ore bodies have been opened up, it has come to be more and more apparent that the ore exists in irregular masses with usually no very well defined walls (except where it lies in contact with limestone.) Further, the deposits are frequently separated by barren zones, so that when the boundary of an ore body is reached it is quite impossible to predict whether more ore will be found beyond or not. Commercially, the low grade of the ore prohibits crosscuts or drifts being run in barren ground solely in order to prospect it, the only allowable dead work being that necessary to reach known deposits.

It is under these conditions of necessary economy and uncertainty of ore occurrences, that the diamond drill has become so useful, not the least of its value being negative, for knowing where the ore is not to be found is only secondary to finding it.

When a new deposit of ore has been located by drilling, it is the practice in our mines to drill no further holes to determine its extent, for the reason that ore occurrences are seldom so limited that it will not pay to drift or crosscut to them; and moreover, the irregularities of the deposits are such that judgments of size based on even a number of drill holes are most unreliable. It is also general experience that ideas of quality based on assays of diamond drill cores and borings are likely to be erroneous, the ore when reached often being as a whole very different from what the drill assays would indicate. Nevertheless, the assays of borings are most carefully made and checked from time to time by assays made on samples of the cores. Borings are carried out by the stream of water and allowed to settle

in a tub; every five feet they are taken from the tub and thoroughly mixed for the sample. Occasionally when the drill penetrates a cave, the borings will not come out with the water, and in such a case the sample must be taken from the cores.

Most of the drilling done under the writer's direction has been by day labour, this having been found to be more satisfactory than contract work, as well as more economical. The result of each day's work is reported by the driller on the following form.

DAILY DIAMOND DRILL REPORT.

Shift ..... Date, ... 6.
Hole No. ..... Level.
Actual Drilling Time ..... Hours.
Depth of Hole at Beginning of Shift ..... Feet.
Depth of Hole at End of Shift ..... Feet.
Distance Drilled ..... Feet.
Amount of Core Saved ..... Feet.
Distance Reamed ..... Feet.

GEOLOGY.

From ..... to ..... Material .....
From ..... to ..... " .....
From ..... to ..... " .....
From ..... to ..... " .....
From ..... to ..... " .....
From ..... to ..... " .....

General Remarks .....

Signed .....
Runner.

These daily reports are tabulated, and the costs of work figured at the close of each month. Drilling by day labour was started in the mines under the writer's charge last Spring, and the following tabulated results may be useful to those contemplating similar work.

The rock while hard, is not excessively so, and the ground rarely caves, and in only one hole drilled so far has the water proved troublesome

1. PROGRESS TABLE.

	Apl. May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Shifts	37	26	26	27	23	27	26	25
Feet drilled	304	253½	259½	295	250	245	278½	356
Hours drill was run	231	167	149½	194	164½	142	170	167½
Hours setting diamonds, moving machine, etc.	57	44	79½	22	19½	101	38	32½
Feet per shift	8.21	9.75	9.98	10.93	10.87	9.07	10.71	16.24
Feet per running hour	1.31	1.52	1.74	1.52	1.52	1.72	1.64	2.13
Carats used	6.$\frac{36}{64}$	6.$\frac{55}{64}$	7.$\frac{42}{64}$	5.$\frac{62}{64}$	6.$\frac{43}{64}$	4.$\frac{9}{64}$	7.$\frac{53}{64}$	2.$\frac{2}{64}$

(Note.—Underground shifts are 8 hours. Surface shifts 9½ hours.)

2. COST TABLE.

	Apl. May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Labour	403.60	272.00	260.88	271.00	210.35	219.60	226.56	231.75
Diamonds	328.81	342.99	382.81	298.45	299.18	227.73	434.85	114.83
Power, etc	13.46	29.10	30.56	26.76	25.13	31.78	18.49	118.97
	745.87	644.09	674.25	596.21	534.66	479.11	679.84	465.55
Feet	304 25	3.5 25	9.5	295	250	245 27	8.5 3	56
Cost per foot	2.45	2.54	2.60	2.02	2.14	1.95	2.44	1.31

Total feet drilled during 1905 is 2,241.5.
Average per shift during 1905, 10.32 feet.
Average cost per foot, $2.1501.
Average cost diamonds per foot, $1.0830

In assaying it has been found that the general tendency is for samples to run too high in gold and too low in copper, when borings are being tested. This is easily accounted for, because the flow of water from the tub in which the borings are settled carries off a greater proportion of copper than of gangue

while on the contrary the gold (much of which is free milling) remains in the tub, thus enriching the sample. On the other hand, when samples are taken from the cores irregularities occur on account of the frequent grinding up of considerable proportions of the core,—grinding which sometimes amounts to fifty per cent.

Some comparative assays of boring and core samples follow:

		Gold	Silver	Copper	Silica	Iron	Lime	Sulphur
Borings	1	.13	.52	2.35	..	..	..	....
	2	.12	.45	2.20	..	..	..	....
	3	.12	.47	2.35	..	..	..	....
	4	.11	.40	2.50	..	..	..	....
	5	.01	.00	.30	..	..	..	....
	6	.14	.00	1.10	29.0	15.1	24.3	3.6
Cores	1	.14	.50	2.50	..	..	..	....
	2	.07	.30	2.30	..	..	..	....
	3	.08	.25	2.10	..	..	..	....
	4	.05	.20	2.00	..	..	..	....
	5	.01	.00	.50	..	..	..	....
	6	.14	.00	1.10	26.9	15.3	26.2	3.4

These assays illustrate in Nos. 1, 2 and 5 the tendency of cores to run higher in copper than borings. Nos. 3 and 4 are given to show cases where the reverse has occurred. Nos. 2, 3 and 4, show a decided enrichment of gold in the borings.

NOTES ON THE UTILIZATION OF POOR COALS AND SLACK.

By D. B. Dowling, Geological Survey, Ottawa.

The lignites are evidently outclassed by the true coals as steam producers, but there seems to be much hope that they will make a better showing in the coming revolution when the ability of a coal to furnish gas will mark its standing as a power producer. The gas producer and the gas engine will in time replace most of the steam plants when it is recognized that the increase in efficiency will reduce the consumption of coal by about sixty per cent. for the same amount of power. This is not at all visionary, but is borne out by many trials and recently on a fairly large scale by the U. S. Geological Survey at St. Louis where many coals were tested in both steam and producer gas plants with capacities of 250 horse power.

Although our Canadian coals were not included in these trials, a series is selected that can be compared within reasonable limits with those that are obtainable in Manitoba, Saskatchewan and Alberta. The selections are made from the preliminary results published in Bull. 261 U. S. Geol. Surv. with the object of showing that even the poorest lignite has as a gas producer a value equal in power production to that of a good steam coal when used in the steam plant.

The relative value of the western coals varies from that of the best as found in the mountains to the poorest lignite of the eastern plains.

The trials with both gas and steam were confined to bituminous coals and lignites, so that our semi-anthracites which are of great value as steam producers are not included.

SELECTIONS FROM STEAM TRIALS.

1. Coal—*W. Virginia No.* 12.—This coal has a fuel ratio 4.13 which classes it as harder than Crows Nest but softer than Canmore.

To produce 1 electrical h.p. per hour required 3.58 lbs. coal = 3.53 dry coal.

2. Coal.—*W. Virginia No.* 4.—Fuel ratio 2.14, similar to softest coal in the mountains and about the same analysis as a seam near Pincher Creek, Alta.

To produce 1 elect. h.p. per hour—3.71 lbs. coal = 3.62 dry coal.

3. Lignite Coal.—*Alabama No.* 2.—This coal is sufficiently like the Lethbridge coal for comparison, but is very high in ash.

To produce 1 elect. h.p. per hour—4.30 lbs. coal = 4.08 dry coal.

4. Lignite.—*Indiana No.* 2.—This coal serves as a comparison for the average Edmonton coal.

To produce 1 elect. h.p. per hour—4.78 lbs. = 4.35 dry coal.

5. Lignite.—*Colorado No.* 1.—Analysis almost exactly the same as for coal from No. 6 level at Stair, near Medicine Hat.

To produce 1 elect. h.p. per hour—6.06 lbs. = 4.85 dry coal.

6. Lignite.—*N. Dakota.*—Two coals similar to the poorest lignite of Turtle Mountain, Man. The one which was tried in the steam plant was not as wet as that tested for gas, so that the results favour the steam trial. For the latter.

To produce 1 elect. h.p. per hour—9 lbs. coal = 6.47 lbs. dry coal.

These six samples show that in making steam we must expect poor results from the lignites of the east, but that they improve toward the west.

The results of the gas tests might be prefaced by a short description of the process employed. Instead of resorting to the crucible method for extracting the gas, an enclosed furnace somewhat similar to an old-fashioned hall stove is employed, to

which the draught is regulated, and the gases are drawn off before combustion, purified and used in a gas engine.

The results are tabulated together below along with those for the steam tests to give a close comparison. The engines, both steam and gas, were belted to an electrical generator and the power measured by water rheostats.

COMPARATIVE RESULTS OF STEAM AND GAS TESTS.

Coal Tested.	Compared with	Consumption per H.P. per hour.				Ratio of Steam to Gas.
		Steam		Gas		
		As used	Dry	As used	Dry	
(1) W. Virginia, No. 12.	Hardest of Crows Nest.	3.58	3.53	1.53	1.50	2.34
(2) W. Virginia, No. 4.	Pincher Creek, Blairmore.	3.71	3.62	1.32	1.29	2.81
(3) Alabama No. 2.	Lethbridge	4.30	4.08	1.71	1.64	2.51
(4) Indiana No. 2	Edmonton	4.78	4.35	1.68	1.55	2.83
(5) Colorado No. 1.	Stair, Medicine Hat.	6.06	4.85	2.14	1.71	2.83
(6) N. Dakota....	Turtle Mt.Man.	9.00	6.47	3.80	2.29	2.37

This table shows in the first column the relative values of these coals as steam producers. The figures may appear too great, but the results are obtained from the electrical power after conversion from the steam engine. If the loss between the engine and generator were considered, less consumption of coal per horse power at the engine would be given. The electrical horse power is used to equalize the comparative results. As the coals were used in a wet state the results for dry coal are added in all cases so as to give a maximum and minimum result.

The table of gas tests shows first that a medium class of coal seems to give the maximum result. Coals harder and softer fall away from this good standard. The wet lignites seem to be poor in heating quality and require apparently the consumption of some of their volatile matter in order to drive off

the moisture and the rest of the gas. The low temperature of the fire merely drives off the moisture and fails to make water gas or to distill the tarry matter and so prevent its condensation in the scrubber. An addition of a coal with high fixed carbon content should improve the showing and an example of the success of this experiment will be referred to later.

Comparing the two trials, it will be seen that even the poorest of the lignites makes as good showing with the gas producer as the best coal does with the steam plant, and all show an enormous saving in fuel. The use of the poorest lignite is therefore justified in producing power, and this should mean a great deal to the West, where it was thought this fuel was fitted only to supply the want of wood.

The altered conditions will be realized very rapidly and the new methods acted upon. As an example let us take Brandon, Manitoba, which is rather remote from the market for high grade coal. The Alexander Milling Co. has installed a producer gas plant which is giving very good results as may be gathered from the following passage in a letter from the manager, dated Jan. 30, 1906:—

"We are now running our plant with a producer gas engine and find that there is a considerable saving of fuel over a steam plant, in fact we figure that we produce power on less than one pound of coal per horse power per hour."

"We use a mixture of Souris lignite and Bankhead anthracite, which we find works to the best advantage as when using the lignite alone we encountered considerable trouble from tar. With the anthracite mixed about half and half we overcame this as the hard coal, making a much hotter fire, eats up the tar."

These results are very satisfactory as the Souris coal is not a high grade lignite and but slightly better than the Dakota sample, yet with an admixture of anthracite it seems to give as good results as the best. This points to a possibility that mechanical mixtures will be sufficient to get the best results from the poorer coals.

If it is possible then let us consider what can be done with some of the lignites. In each case the value seems to be dependent on the amount of gas produced, since in the tests the amount of power obtained from a given quantity of gas remains fairly

constant. This will be seen in the table below for the same coals as already cited in the first table.

GAS PRODUCED.

Coal from	Wet coal	Dry coal	H.P. from 1000 c. feet.	Thermal units in 1000 c.f.
1. W. Virginia, No. 12	62.1	63.2	10.0	142 500
2. W. Virginia, No. 4	70.6	71.9	10.2	143 200
3. Alabama, No. 2	52.9	55.0	10.6	149 180
4. Indiana, No. 2	51.6	55.9	10.9	159 300
5. Colorado, No. 1	35.8	44.9	12.1	149 000
6. N. Dakota, No. 2	22.7	37.5	10.8	188 500

There is here a great variation between the highest and those below and if we take the composition of W. Virginia No. 4 as the best, mixtures such as Lethbridge 4 parts and Bankhead 3 parts would closely approach it and might be expected to give as good results or an increase in efficiency of 34% over Lethbridge without admixture. Again a mixture of 3 parts Stair coal with 2 of Bankhead should give an increase in efficiency over Stair of 100%.

These suppositions are added merely to point out the possibilities there seem to be for investigations if the experiments could be made with the many grades of coal to be had in the west.

Another glance at the table is requested in order to point out the heat producing power of the gases. In the last column is indicated the total amount of heat in the same quantities of gas given and there is really a comparison of the relative temperatures of the flames from each. If the gas flame be found useful in the arts the lignites have the first place since their gases give the hottest flame.

We are evidently wasting money using illuminating gas for fuel in our homes when the production according to these figures of a purely heating gas should cost about 15 cents per thousand feet. A town in the west well supplied with lignite at from $3.00 to $4.00 per ton should have a producer gas plant to use lignite

—heat the houses with gas at ten cents per 1.000, use the gas engine for electric lighting and water supply and run all the factories by the same means of producing power.

In the results for the steam trials objection may be raised to the rather poor showing made by even the best of the coals, but this is partly due to the fact that only one type of boiler was used for all fuels and also to the simple type of engine employed. In large factories the efficiency will be increased by compounding the engines, but the experiments should represent very nearly as good results as will be obtained in an ordinary steam plant. This low average will probably be offset in some measure by the improvements that are likely to be made in the gas engine judging by the improvements that have been made in the gasoline machines since they have come into general use.

A point that seems of importance in the use of the gas plant is the possible isolation of the gas producer from the larger works since the gas can be carried greater distances without the great loss that is found in steam pipes.

Coal Slack or Breeze.

The cement factories have demonstrated that a fine powder can be burnt in the furnace by blowing it in as a fine spray forming a long flame. The same process seems possible also for other heating devices. Experiments have shown very conclusively that it is possible to use very small coal in the ordinary furnace by forming it into briquettes by the addition of a binder. The material generally used is a tar, and it is added as a fine dust and then heated and pressed with the coal dust. A later device mixes the warmed coal dust with a spray of vapourized pitch so that each particle receives a thin coating of the binder and so makes a very homogeneous mass when pressed. The low grade lignites are difficult to press as they seem to hold so much moisture that the steam that is given off from each particle prevents the pitch from adhering: the only remedy seems to be a more thorough drying at a temperature that will almost cause ignition.

If the gas producer method of obtaining power comes into general use a large supply of tar will be available for briquetting.

Another opening that is suggested for the use of the fine coal

is in the making of coke, but there is only a small range in the different coals that will coke naturally. The admixture of different grades in the fine state may repay the expense of experiment, as it has been found that briquettes of a non-coking coal will make a good grade of coke. This might suggest also that mixtures of such coals as the Canmore, which is just a little too hard to coke, might be made with some of the coals in the foothills that are too soft to make hard coke and so produce coke that would be useful. The possibility of coking the anthracite dust at Bankhead may seem visionary, but a successful series of experiments on Welsh anthracite, which is very much like the Bankhead coal, was made and carried out on a comparatively large scale. The details of the process are to be found in a paper by Mr. W. Hackney, read before the Iron and Steel Institute in 1865, and are briefly as follows:—A mixture of anthracite and bituminous coal with pitch was made in proportions of anthracite 60, bituminous 35, and pitch 5. The mixture was ground and burned in a long Welsh oven fired by spreading a layer of soft coal over the top and introducing hot embers. The ovens appear to have been but partly filled as a charge of only four tons was put in each oven. The space at the top was probably required to supply air to start the combustion. The manufacture of this coke was carried out at intervals only, but a very hard coke was obtained and a considerable quantity was made during several years.

DISCUSSION.

Major Leckie.—We are indebted to Mr. Dowling for one of the most important papers that has come before the Institute, because power, and how to obtain it economically, is of great importance to the miner. We have enormous deposits of peat in different parts of Canada, and attempts have been made to make coke and all sorts of things out of peat. In every case it has been a financial failure, but the simplest and most direct way is simply to convert the peat into gas. I have seen it in Sweden

where they use wet sawdust, and sawdust carrying a less percentage of gaseous matter. Air treated peat gives about 30% gas, and the sawdust direct from the mill makes about the same percentage. A man in Lundgren, I think, was the first man in Sweden to use sawdust, and you will find in Sweden some of the best steel made by gas, produced from sawdust and from peat. Peat gas has, futhermore, thé quality of being very free from sulphur, which usually is a very injurious ingredient. To get a good quality of gas depends a good deal on the nature of the producer. If in the ordinary lignites you carry a sufficient amount of moisture, and if by some secondary arrangement you can convert the moisture into CO and hydrogen, you get the most intense heat of gas, instead of the moisture being a waste. We have been running, in the way of smelting with the ordinary tubular furnace, as they have at Copper Cliff, at Mr. Hixon's works, and in British Columbia, but there are places where you usually find ore that has been calcined; a great deal of that will blow away in the shape of dust, but if you have the right kind of fuel like lignite or peat, or even wood, and convert them into gaseous fuel, you can use the reverbatory furnace.

Dr. PORTER.—I am very much interested in the subject of Mr. Dowling's paper, and for the last two or three years have been carrying on some investigations on western coals. I may, therefore, be permitted to say that I look upon the paper as one of the most important that has come before the Institute for a long time. Mr. Dowling has brought out more fully than has ever been brought out, in connection with any of our Canadian coal, the fact that the gas producer has the happy quality of getting the best results from poor coal, or rather of getting a standard fuel out of the poorer grades of coal. The gas producer is thus the saving thing for the bad coal, and has made it possible for Canadian engineers to enjoy the enormous advantage to be derived from the use of poor, but cheap coals.

Blending the coals, particularly in connection with the gas producer, has I think been done to a certain extent, but no one has explained its advantages upon it so admirably as has Mr. Dowling. In his suggestion that we can take the waste of the anthracite mines, (and they are bound

to make a very large percentage of stuff, which is worth little or nothing) he has brought before us the means of increasing the efficiency of our lower grade coals. All through the west we have these low grade coals. There is a somewhat allied matter which I think may be properly brought up in this same connection. I have been carrying on experiments recently on a comparatively large scale, on the washing of some of the poorer Western coals. Everybody knows if you take a coal and wash it, you can improve it ten or fifteen per cent. by eliminating ash; but the full advantage of doing this is not always appreciated. For example, if you take a coal with twenty per cent. ash, and burn it under the boiler, you have to clean the fires at least once an hour, which takes ten or fifteen minutes. While the cleaning is being done little or no steam is made, but the coal burns on as fast as ever. You thus suffer not only the trouble and expense of using a low grade coal, but you waste one-fifth of your steam. If you wash the coal you need only clean your fire once in twenty-four hours or once in twelve hours instead of once an hour. Washing is of course done at the mines. You therefore save freight on the waste material, greatly increase your steam production per unit of boiler, lessen labour and repair bills, and get a more uniform steam output. Actual experiments on coal from some of our mines in British Columbia and Alberta, show that the above statements are not exaggerated, and their importance to consumers of raw coal is very great.

In calling attention to the use of low grade and mixed coal, Mr. Dowling has pointed out a method which, when practicable, offers many advantages over washing. It will prove of especial value in the middle West. Dr. Dowling has also suggested one thing which I think should be brought to the attention of every member of the Institute: that every man using coal should study the coals that are available. Each consumer of coal has the choice of a certain number of coals, which may or may not be offered at different prices. It is not always the dearest or the poorest coal which is going to give the best results, and the right thing to do is to experiment, and then blend or wash as the case may be, and thus get the maximum amount of power for the money expended.

MAJOR LECKIE.—The mixture of bituminous and anthracite is a very old idea. A patent was taken out by Bessemer for making coke with this mixture.

Mr. DOWLING.—1865 is the date of the patent referred to.

Mr. INGALL.—Did you work the results out in dollars?

Mr. DOWLING.—No, I did not, because I could not get the market value of all these coals.

Mr. INGALL.—Mr. Dowling has shown us the tremendous possibilities of developing power, out of the poorest of fuels, and I am sure we all agree that the paper is a most important one.

PRESIDENT SMITH.—Speaking of the gas producer plant: On a 750 horse-power plant the figures run about $30,000 for the installation of the plant. It is very heavy, but the coal saving has generally been sufficient to warrant the installation.

STUDENTS' PAPERS

THE BRITISH COLUMBIA COPPER COMPANY'S MINE AND SMELTER.

By *Frank G. Wickware, McGill University.

MOTHER LODE MINE.

Location.—The Mother Lode Mine is located in Deadwood Camp in the Boundary District of British Columbia, about three miles west of the town of Greenwood with which it is connected by an excellent waggon road and by a spur from the Columbia and Western Division of the C.P.R. The B.C. Copper Co. now owns a group of six claims in this camp but the Mother Lode Mine lies wholly within the boundaries of the Mother Lode claim which was the first located, though the others are conveniently situated for the most advantageous working.

History of Company.—The Mother Lode claim was staked on May 28th, 1891, by Wm. McCormack and the location recorded in the name of himself and two others. Very little work was done on it for the next few years, other than the assessment work necessary to hold the location until, in 1896, it was bonded for $14,000 to Col. John Weir, F. L. Underwood and J. F. Tichenor, of New York. These gentlemen at once formed the Boundary Mines Company to develop the mine, and the work, which was begun in September, 1896, soon disclosed such an immense body of ore that the property was purchased outright. In March, 1898, the British Columbia Copper Co., Ltd. was organized in New York and incorporated under an extra-provincial charter to acquire and operate the Mother Lode Mine and to purchase adjoining claims. Its capital was at first $1,000,000 but in 1902 it was increased to $2,000,000 in shares of $5 each. Of this stock 353,000 shares have been issued, leaving 47,000 out of the original 400,000 in the treasury. The property has been worked continuously ever since its purchase. The scale of operations has been

*Student's Paper sent in for competition and awarded President's Gold Medal and First Prize.

increased, improvements have been made and other properties and equipment purchased until now the Company ranks as the second largest producer of the district. The engineer of all mines of the Company is Mr. Frederic Keffer, M.E., and the superintendent of mine, Mr. S. C. Holman.

Ore Deposits of District.—The latest and best report on the Geology, Mineralogy and Ore Deposits of the Boundary District is that of a Geological Survey made of the district in 1902 by Mr. R. W. Brock and contained in the Summary Report of the Geological Survey of Canada for 1902 and, in a shorter form, in a paper read by Mr. Brock before the Canadian Mining Institute in March of the same year.

The Mother Lode Ore Body.—The ore body of the Mother Lode is in many respects typical of the low-grade copper deposits of the Boundary but it also possesses several features of its own. Its size is immense, north of the main shaft it is traceable by continuous croppings for some 1,100 feet to where it disappears under a heavy drift while to the south it extends at least as far as the Primrose shaft, some 700 feet. Hence its length is very close to 2,000 feet. On the surface, the width varies from 80 to 160 feet and, taking into account the underground explorations, it will probably average 140 feet though its boundaries are somewhat indefinite. It is continuous to the 300 foot level which is 500 feet below the highest croppings and a diamond drill hole sunk 143 feet below the 300-foot level in August of this year showed excellent ore throughout its entire length.

Though the croppings assume a somewhat crescent shape, the general strike of the ore is north and south and in this it follows the general rule of the district. Its dip is from 55° to 70° toward the east.

The ore is of the magnetitic type described above though a small amount of pyrrhotite is present. The minerals found in the ore are magnetite, chalcopyrite, pyrite, a very little of zinc-blende, galena and pyrrhotite and an occasional trace of arsenopyrite, calcite, actinolite, garnet, epidote and quartz. Unlike the Knobhill-Ironsides deposit, it contains no specular hematite but the Mother Lode ores may be divided in the same way into three classes.

1. Silicious, containing silicates of calcium, magnesium,

aluminium and iron with massive or disseminated copper and iron pyrites, and occasionally zincblende, quartz, garnets and epidote.

2. Calcareous, containing calcite (some excellent crystals of Iceland spar have been found) and quartz with massive or scattered copper and iron pyrites and, on the 200-foot level, some galena and blende.

3. Ferruginous, consisting of a fine grained magnetite with quartz and chalcopyrite.

The following partial analysis illustrates the difference between the three classes.

	1. Silicious	2. Calcareous	3. Ferruginous
Silica	44.23	20.10	27.33
Alumina	7.46	1.31	.....
Iron Oxide	16.83	12.00	51.12
Lime and Magnesia	16.03	34.00	10.26

The rock on the west of the ore body which forms the footwall is a very pure white crystalline limestone and on the east the hanging wall, "a green fissile epidote-like material" which Mr. Brock considers to be argillite but which is commonly called a diabase. In some places the limestone contact is sharply defined but in the majority of cases in which the footwall has been encountered the ore grades into the country rock outside of the ordinary boundary of the ore body. On the hanging-wall side, however, there is a more or less sharply defined transition from ore-bearing to barren rock. The metallic minerals fade away completely within a foot or two though the chemical composition of the hanging wall and of the ore lying against it—leaving out the pyrites—is substantially the same. Mr. Brock considers that the western part of the ore body will prove to be altered limestone and the eastern, altered argillite. To the north of the lode the rock is a greenstone and Tertiary lavas are found in abundance on the neighboring hillsides while to the south, across the ravine, the rock appears to be argillite. Heavy dikes of pink alkali-syenite porphyry traverse the whole country and one large and two smaller ones run through the ore body nearly at right angles, lying almost horizontal but with a low dip to the south

and west. The ore lying along these dykes carries rather better values than elsewhere and hence it is considered probable that these dykes afforded means of ingress for the mineralizing solutions. More than one ore shoot occurs and on the lower levels two are well defined. The Mother Lode is unique in the district with regard to surface oxidation. A large copper-stained blow-out covered the whole hillside and, being visible for miles, made the prospector's task an easy one in discovering this location.

The ore carries values in copper, gold and silver. A conservative estimate places the average value of the ore per ton of 2,000 lbs. at from $4.50 to $6.00. With regard to the distribution of the values in the Mother Lode ore Mr. Brock says, "The silicious ores carry a little silver as well as gold and copper. The blende and galena are argentiferous. Magnetite and pyrite as a rule are not highly auriferous, but in the 'Keffer stope' (300-foot level) the magnetite carries an unusual proportion of gold. The chalcopyrite, when present in such quantities that the ore runs 2% copper, seems to be the best gold carrier, but when nearly pure, running 30% copper, it carries no gold."

History of Mine Development.—During the five years between the location of the claim in 1891 and its bonding to the Boundary Mines Co. in 1896 very little work was done on the Mother Lode. In September of the latter year, however, surface prospecting was begun by means of trenches and, in the following year, the tunnel marked No. 1 on Plan A was commenced. By March, 1898, this tunnel was in 245 feet and was run in ore for 203 feet of its length. At a point 152 feet from its mouth, a winze was sunk for 100 feet also in ore.

Allowing for the inclination of the direction of this tunnel to the strike of the ore body, it was estimated that the ore was 185 feet wide at this point and on this excellent showing the British Columbia Copper Co. was formed with a capital of $1,000,000. A temporary head frame was built and sinking on the main shaft was begun which by the end of the year was down 25 feet. Several drills were purchased and a power plant was installed

which consisted of two 60-h.p. boilers, two Cameron pumps, a Lidgerwood hoist with 30-inch drum and an Ingersoll-Sergeant compressor with a capacity of ten drills. By October, 1899, the main shaft had been sunk 280 feet and the north drift on the 200 foot level had been driven 450 feet. In the fall of this year, also, the preliminary work for the construction of the smelter was undertaken and the railway spur to the mine was completed. Great activity marked the next year. Early in the spring the present head frame was built to replace the temporary structure and by the time it was finished the shaft was down to 325 feet, its present depth, and the 300 foot level had been opened. The old hoist and compressor were disposed of and, in their place was installed the present equipment which will be fully described later. Four more boilers with a total of 360 h.p. were installed and the two old ones were taken to run the new crushing plant, a No. 5 Gates crusher and a 70 h.p. Nagle engine. Several new drills, several 3-ton cars and two cages with bonnets and safety clutches were also added to the equipment. To supply light to the mine and surface works, a small dynamo and engine were purchased and to handle the ore, a complete system of belt conveyors was installed by the Jeffrey Co. Temporary ore bins were constructed near the present ones and a hand-picking shed built to connect them with the crusher, which was placed near the shaft. The ore sorting plant was the first introduced into the Boundary and consisted of a 30-inch Robins belt 111 feet long with a return conveyor 41 feet long, 110 feet of 12 inch fine ore belt and 555 feet of 16-inch belt to handle the waste. All ore was dumped into bins over the crusher from the cars. Early in 1901, the smelter began operations and as it was found advisable to cease work for a time on the lower levels, the glory hole was begun on the big outcrop. Four quarries connected by raises were begun at different levels on the hillside and the ore from them was trammed out No. 2 tunnel on Plan A to the crusher, this short tunnel having been driven for the purpose.

The shops and present ore bins were built during the summer of 1900. Also during this year the south drift on the 200-foot level was extended to the surface, immediately behind the compressor house to dispose of water and to allow the air pipes to be carried to the shaft underground. Early in 1902 the "mule

tunnel" was commenced. The Gates crusher was lowered to the ground level, and to handle the mule tunnel ore a Jeffrey elevator with 10 x 9 x 12 inch buckets was purchased. Since 1902 however, the main source of the ore has been the quarry. As the mule tunnel progressed, raises were run to the glory hole to draw off its ore and the ore trammed to the crusher at its mouth, particularly as the quarries soon got too deep to allow ore to be cheaply trammed in cars out No. 2 tunnel. In 1903, tunnel 4 on Plan A was driven to the shaft and early in 1904, the main drift was run to connect with the mule tunnel, the pocket being blasted out at the same time. Last winter, the present crusher house was built and skips substituted for cages in the shaft. Early in the spring the whole of the ore was hoisted to the Farrel crusher and extensive development operations were begun on the 60-foot level with a view to opening up stopes, one of which has already been begun. Hence the general method of mining at present is a combination of open cutting and the pillar and stope system below ground, though, so far as the 60-foot level is concerned, the latter is only in its infancy. An idea of the present extent of the workings may be gained from the accompanying plans of the levels, though the quarry is much larger and deeper than shown on Plan B which was made early in 1904.

Timbering.—No timbering is necessary to hold the ground in the Mother Lode as the rock is very solid. At intervals, an examination of the roof of the workings is made and any loose pieces of rock barred down but nothing further is necessary to render the mine safe. Hence, practically all the timbering is done in connection with the stopes. On the 300-foot level there is no timber whatever. On the 200, however there is considerable, due to the immense size of the stopes and the fact that they extend considerable distances on both sides of the main drift. Some few cribs are to be seen in the largest stope on this level but most of the timbering has been done in order to minimize handling of ore and allow cars to be loaded from chutes instead of by hand. This applies also to the single stope on the 60-foot level and it is timbered in practically the same way. A couple of tiers of 8 or 9 inch lagging are supported on heavy horizontal timbers, placed about 4 feet apart and these are in turn supported by very heavy uprights about 6 feet long placed

rather close together. On the average they are probably not more than 30 inches from centre to centre. This method has been found to form a sufficiently strong floor for the stopes. Chutes of the ordinary type are introduced wherever needed by simply cutting away sufficient lagging. The method of constructing chutes will be mentioned in another connection. On the 200-foot level, where the main stope was driven to a great height, the chutes were set in hollow cribs into which the ore was directed. The cribs were kept built up close to the roof and hence enough ore could be kept in the stope to prevent the necessity of building staying in order to reach the roof. When the desired height had been reached it was only necessary to begin to tear down the crib from the top to enable all the ore to be drawn off.

On the 200-foot level, the main drift is continuous as the main tracks have been protected where they pass through the stope by a system of timbers which is practically an extension of ordinary drift timbering. A heavy collar is supported by a vertical leg about 2 feet from each end and outside these, there is an additional leg. These sets are placed about five feet apart. Heavy lagging is placed on the sides and top, the whole forming a perfect protection to the tracks and tramming operations.

The drainage tunnel on this level is also timbered and lagged for about 300 feet of its length, the ground being somewhat soft.

Light.—Ten inch Stearic wax candles are used underground, each man being allowed three per shift. The greater part of the mine is, however, lighted by electricity, and all the surface buildings are supplied with electric light. The power is supplied by a 15 K.W. Westinghouse dynamo placed in the compressor house, rated to supply 120 Amps. at 125 volts and having a capacity of 250, 16 c.p. lamps. It is run by a 20 H.P. Armington and Sims engine operated by steam, the cylinder being 8 x 12 inches. The engine works at 235 r.p.m. and the dynamo at 1050.

Exploration.—About a year ago the Company purchased a diamond drill and since that time all prospecting has been done by this method. The drill has been kept steadily at work ever since its purchase and in all, about 3,000 feet of drilling has been done. The majority of the holes have been sunk underground but the drill worked for some time on the edge of the glory hole,

determining the exact location of the foot and hanging walls. The machine is of the screw-feed, double geared, Bullock type and is capable of drilling 800 feet vertically or 700 horizontally. Two men are kept steadily at work on it and the runner sets his own diamonds. A $1\frac{1}{2}$ bit is used and the core produced is $\frac{7}{8}$ inch in diameter. From 6 to 8 diamonds with an average weight of $2\frac{1}{2}$ carats are used in each bit and it is estimated that about 70 feet are drilled per carat. No diamonds have been lost as yet but they chip frequently owing to the numerous cracks which traverse the rock and the abrupt transition from soft to hard material. It is found that the best progress is made in the solid, hard ore, and as much as 27 feet has been drilled in one shift under these conditions. The chipping of the limestone necessitates frequent removal of the core and makes it the slowest rock to drill. About $10\frac{1}{2}$ feet per shift would probably be a fair average drilling. The drill is run by air and requires about 7 h.p. No accurate record of costs per foot were available but from $2.00 to $2.25 would probably be close to an average cost.

Drilling.—All drilling is done by machines, the power used being air, delivered at a pressure of 85 to 100 pounds. Underground, the holes rarely go over 7 feet in depth but in the glory hole 12 feet is the average depth of hole. Hence the bits used range from 2 to 14 feet in length. All the bits used are of the Maltese cross shape and the sizes vary from $1\frac{1}{4}$ to $3\frac{1}{2}$ inches. Sharpening was formerly done by hand, two men being kept at work day and night but in August of this year, a mechanical steel sharpener, said to have a capacity of 1,000 steels a day, was installed and it is expected that all the steels necessary for two shifts can be sharpened in one. In sharpening, the practice is to quench from a bright red heat all but the very point of the drill and to cool the latter at a cherry red. Of course, columns are used almost exclusively underground and they are kept in lengths from $2\frac{1}{2}$ up to 12 feet. Two men, both machine men, are kept on each large drill, chippies being operated in most cases by one. The magnetite offers the greatest resistance to drilling and 30 feet in one shift is the best that has been done in that class of ore, the sulphides on the other hand are very easy to drill and as much as 70 feet has been drilled in one shift with six changes of position. Both Ingersoll-Sergeant and Rand drills are

used. Below is given details of the drills in use at the Mother Lode:

	Rand No. 0	Rand No. 1	Rand No. 3¼	Sergeant "Auxiliary Valve"
No. in use	2	2	2	12
Cyl. diam.	2 in.	2¼	3¼	3¼
Stroke	4 in.	5½	6½	6½
Weight	105 lbs.	150	310	246
Change bits every	12 in.	15	2 ft.	2 ft.
Mill drill vert.	2 ft.	4	15	14

The following is the drilling record for the first six months of 1905, a total of 156 days. The Baby drill referred to was employed in running a manway alongside the shaft timbers:

	Development	Stoping	Quarry	Baby
Shifts worked	312	121¾	156	130
Drill shifts worked	1002	121¾	538½	130
Holes drilled	6307	581	1126	769
Feet drilled	38304	3630	12764	2155
Steels dulled	19737	2149	7787	1169
Cars of Ore	17483	1220	30263	190
Tons of Ore	27930	2440	61084	380
Av. No. of drills per shift	3.2	1	3.5	1
Av. No. of holes per drill shift	6.3	4.8	2.1	5.9
Av. No. of feet per drill shift	38.2	29.8	23.7	16.5
Av. No. of steels dulled per day	198	.....	.....	.....
Av. No. of steels per drill per shift	19.7	17.4	14.5	9
Av. No. of feet per steel	1.9	1.7	1.6	1.8
Av. depth of hole	6	6.2	11.3	2.8
Av. No. of tons per foot of hole	.73	*.67	4.79	.02
Av. No. Cars per shift	56	10	195	1.3
Av. No. Tons per day	179	15.6	391.5	2.8
Av. Carload	2 tons	.....	.....	.....
Daily output	588 tons	.....	.....	.....

*Three-fifths of stoped ore is left in stopes, until stopes are finished, when the ore is withdrawn, hence the above figure is misleading.

These average figures are far from accurate, particularly in regard to the quarry and stope. It must be remembered that besides the time lost in moving machines, the miners do their own blasting and much time is lost in this way. Further, there is no special time set apart for blasting and there are delays waiting

for the face to clear underground. On Tuesdays and Fridays, no drilling is done in the quarry, the long holes are fired one at a time, and the large rocks "bulldozed." There is also considerable bulldozing necessary in the stope.

Explosives and Blasting.—The only explosive used is dynamite and three grades are used—40, 50 and 60%. The 60% powder is used entirely underground and also in the long holes in the glory hole. Forty and fifty per cent. dynamites are used indiscriminately for bulldozing. The 60% grade is supplied by the Giant Powder Co., Victoria, B.C., and the lower by the Hamilton Powder Co. of Nanaimo, B.C. Prices range from $15 for 40% to $18.00 for 60% per 100 pounds in carload lots, and, of course, no smaller quantity is ever bought. The main magazine is situated on the hillside towards Greenwood about 500 yards from the mine and is merely a strongly built wooden structure with a capacity of about 30 tons. The secondary magazine, from which the immediate wants of the mine are supplied, is just below the mouth of No. 1 tunnel. It is strongly built of wood and is protected as much as possible from frost and dampness, being built right into the side of the hill. Steam coils are placed in it for the purpose of thawing the powder in cold weather. About 30 boxes are continuously kept on hand. Powder for use underground is taken in every morning in 50 pound lots and stored in strong chests placed in convenient spots in unused workings. Holes are loaded from this supply and only the amount immediately necessary is taken into the face at one time.

Firing is done entirely by fuse, this method being considered superior to battery firing. Two kinds of fuse are used: Harrison fuse, comparatively cheap, running 28 seconds per foot, and Bennett fuse, a more expensive grade and much slower running, 40 seconds per foot. The former is not much used as it is not dependable but the latter is an excellent fuse and can be depended upon to burn consistently. A difference of two inches in lengths of fuses for a round of holes enables the shots to be easily counted. The fuses are cut into lengths, in the office, and the ends inserted into caps. No particular kind of tamping is used and all tamping is done by hand. In loading holes each stick of powder is rammed down separately. The cap and fuse attached is inserted in the top stick by cutting a hole in the paper and the hole is usually

closed by filling a paper cone with dirt and dropping it into the hole. Misfires are very infrequent and the cause can always be traced to the fuse. When a misfire occurs, it is at once reported to the shift boss who sees that the charge is drawn immediately. The miners do their own blasting, and underground there is no special time set apart for blasting but the heaviest firing usually occurs when the men are coming off the shift. In the glory hole long holes are fired on Tuesdays and Fridays but bull-dozing goes on at any time. In bull-dozing two or five sticks of powder are laid on a block of ore, a couple of shovelfuls of dirt are put on as a cover and the charge fired in the usual manner. This is doubtless wasteful of dynamite but no blockholing is done because it has been found cheaper to waste powder than to spend time in drilling blockholes. When firing is going on in the Glory Hole there is some danger down below from flying rocks. Hence all the roofs of cottages and bunk houses, etc. are heavily lagged and whistle signals are blown to give warning of blasts, to enable those below to go to one of the numerous block-houses provided for the purpose.

It is considered that approximately one pound of powder is needed to break down a ton of rock.

From the available records for June last the cost of explosives amounted to $2,995.15

The combined cost of drilling and blasting was as follows:

	Quarry	Stoping	Development
Tons of Ore extracted	9260	640	6070
Costs of Drilling and Blasting	1496.37	384.49	1651.14
Explosives	1969.56	265.13	760.46
	3465.93	649.62	2411.60
Average cost per ton	37.4c	*$1.01	39.7c

*See foot note page 00.

These figures may be taken as correct.

Tramming.—As has been previously noted the quarries are connected with the mule tunnel by a series of six raises into which all quarry ore is directed. To minimize handling of ore, the tops of these raises are kept funnel shaped and only a small

part of the ore requires to be mucked down from the sides of the quarry. Very little preliminary sorting is done. While the pits remained shallow it was an easy matter to remove barren or very poor rock by loading it into cars and tramming to waste dumps, but as the funnel system developed, it became inadvisable to remove any except very large bodies of waste as the cost of sorting had become greater than the cost of smelting. These large bodies of waste such as are encountered in the dykes of epidote and alkali porphyry are removed by blasting into the raises, all the ore having been previously withdrawn.

At the bottoms of the raises, chutes are built and though they are rather primitive in construction they serve the purpose very well. They are about 9 feet long, 4 wide and 3 deep and are strongly constructed of 3 inch planking. The upper end fits into the bottom of the raise, the remainder of the opening being covered by heavy lagging supported by timbers let into deep hitches and the lower end is either supported on blocks or on a cross piece mortised into two heavy uprights. The gates are merely pieces of planking working in cleats on the side of the chute, and though they have to be opened and closed with the aid of a crow-bar, the car loaders have very good control of the ore as it runs out. The two chutes from the stope are identical in construction.

From the quarry and stope chutes, the ore s loaded into three ton cars and drawn to the shaft in trains of three or four cars by horses. These cars are of a very heavy, solid body type and are built entirely of steel. A detachable brake is usually put on the rear car but the grade of the track is not such as renders a brake very necessary. There are twelve of these cars running constantly.

The gauge of the tracks is 30 inches and the grade about 2 inches in 100 feet which will just allow a fully loaded car to run. Twenty-six pound rails are now used altogether, set on 3 foot ties of 6 x 4 inch timber. Split switches, easily set by the foot and the ordinary type of frog are employed.

From the faces of drifts and cross-cuts, the ore is mucked in most cases into shallow, 1½ ton, end dump cars and trammed by hand to the shaft. At the shaft, the cars discharge into two ore pockets. The smaller one opens into the shaft about

25 feet below the 60-foot level and holds about 175 tons. The other holds 300 tons and discharges about 15 feet below the former.

Shovelling and tramming costs for the month of June were as follows:

	Quarry	Stope	Development
No. of tons extracted	9260	640	6070
Cost, labor	1556.63	48.25	1053.77
Cost, tools	12.78	3.00	18.38
	1569.41	51.25	1072.15
Cost per ton	16.9c	8.0c	17.7c

Hoisting.—The shaft* consists of a manway and three compartments, each 4½ x 5 feet, inside dimensions. It is timbered throughout with 12 x 12 timbers and the work has been exceedingly well done, the adjustment being almost perfect. The manway at the side of the shaft was driven during the past summer and a continuous ladder run down to the 300-foot level. The ladder is very strongly built, the rungs being of 1 inch pipe let into 6 x 6 timbers and it is securely fastened and spliced. Stages with trap doors are placed at short intervals in the manway and here, as everywhere, the extreme care taken by the Company to minimize danger to life, is seen.

While work was being done on the two lower levels, the cars of ore were hoisted in cages but these have been replaced by solid steel skips weighing 1,400 lbs. and having a capacity of five tons. The skips are simple in design but extremely good. They are, of course, equipped with safety clutches and arrangements for self dumping. Into them, the ore pockets are discharged, two men being required to operate the gates. In this case the gates are opened and closed by means of compressed air.

The head frame is about 58 feet high, is simple in design and at the same time, cheap and strong. It is built entirely of 4 x 18 inch planks, securely bolted together and rests on masonry foundations. The sheaves are 6 feet in diameter and for their protection in winter a hood has been built over them. A simple

*The shaft is now being made four compartments, each 4½ x 5.

but efficient self dumping arrangement, designed especially to prevent the possibility of rocks falling down the shaft during dumping, wasadded to the headframe when the skips were introduced.

One and one-quarter inch rope is used and to preserve it a mixture of linseed oil and tallow is applied at short intervals of time. Outside the hoist house, the cables work in guides, consisting of 2 foot sheave wheels running loose on a $1\frac{1}{2}$ inch iron rod.

The hoist is one of the largest and best in the Boundary. Originally it was run by steam, two 80 h.p. boilers supplying power for crushing and hoisting but it is now run by air. The air is supplied from a receiver at the top of the shaft and before entering the cylinders is preheated by means of a coil of steam pipes placed about the intake. The engine was supplied by the Jenckes Machine Co., of Sherbrooke and is of the first motion, simple Corliss type, rated at 200 h.p. Air at 100 lbs. pressure is supplied to the cylinders of which there are two, each 20 x 42 inches. Reversing is done by the ordinary sliding link method. There are two 6-foot drums which may be run singly or together. As a matter of fact the hoist is always run balanced. The brake is the ordinary friction brake placed on the drum and shod with wood. The tell-tale is attached to the shaft with three sets of bevel gears and the system of signals fixed by Statute is used.

Crushing and Shipping.—The ore after leaving the skip runs down a chute to a Jenckes Farrel crusher with a jaw opening of 23 x 36 inches capable of crushing 100 tons an hour to five inch size. This crusher is run by a 90 h.p. engine by the Erie City Iron Works with 18 x 24 cylinder and 18 inch stroke working at 100 lbs. air pressure. The air is supplied from the same receiver as the hoist and is preheated in a large stove before entering the cylinder. When ore sorting was practiced, the crusher stood some 30 feet nearer the ore bins and the ore dumped into a grizzly before being conveyed to the crusher, the fines being carried to the bins by a separate belt. Now a 36 x $\frac{3}{8}$ inch Robins belt with guides every four feet, a remnant of the old ore sorting plant, conveys the crushed ore to the top of the ore bins, the power being supplied by the crusher engine. The ore bins are four in number, each of 150 tons capacity; only three, however, are now

used, bin 4 being used originally exclusively for fines. The convey or discharges over bin 2 and the ore can be directed by means of gates into either 1, 2 or 3. From these bins the ore is loaded directly into railroad cars, each bin discharging through two chutes which can be drawn up out of the way when not in use. One man loads the cars as fast as they are needed.

The spur from Greenwood is about four miles long and is owned and operated by the C.P.R. Two trips of 8 to 10 33-ton ore cars are made daily, about 600 tons being the average daily output.

Pumps and Water Supply.—The Mother Lode is dependent for its water supply upon a small stream which runs through the gulch about 220 eet below the shaft collar and owing to the smallness of the supply every possible means of saving and economizing water is used. The stream is dammed about 500 yards above the compressor and the water is carried by a wooden flume of 12 x 2 inch planks to two tanks of about 5,000 gallons capacity each situated behind the compressor house and at a slightly higher elevation. Considerable water, however, escapes over this dam and the stream is dammed again in front of the boiler house where a considerable pond is formed. This is fed also by the exhaust from the compressor and the sump water from the mine. The mine is singularly free from water and the sump is kept clear by a 6 x 4 x 7 inch Northey Duplex pump placed at the 300-foot shaft station and working about 4 hours a day. The pipes are carried up the shaft to the 200-foot level and out the drainage tunnel. This pond water is pumped to one of the tanks by means of two $5\frac{1}{4}$ x $3\frac{1}{2}$ x 6 Northey Duplex pumps housed at the dam. A pump similar in size and make is placed in the boi'er room to feed the boilers and also one of the larger size, which raises water from the tank containing the purespring water, to two tanks placed beh nd and above the hoist house from one of which the town is supplied. This pump works only a few hours every day and can be used to supply the boilers in case the other breaks down. From the smaller of the two upper tanks the quarry and No. 1 tunnel drills are supplied by means of a 3 x 2 x 3 duplex pump by the Snow Steam Pump Works, Buffalo, while a $2\frac{3}{4}$ x $5\frac{1}{2}$ x 6 Knowles duplex is used to supply the diamond drill.

Boilers.—There are four 16 x 66 horizontal return butular

boilers in the main boiler house near the compressor, two of 100 H.P. and two of 80 h.p., all supplied by Jas. Cooper & Co., Montreal. Only three, however, are in use at any one time. These boilers are rated to deliver steam at 105 lbs. pressure. The feed water is heated up to 180 degrees by the exhaust from the small dynamo engine and afterwards passes through a heater where condensed steam from the compressor still further raises the temperature. It is then fed into the boilers at the top by means of an injector and a small duplex pump. The furnaces are 8 x 4 feet with 1 foot bank. Fernie coal is used and is found to be very dirty. About 5 tons are used per day, the greater part being used during the day shift. The boilers are blown off every day between 4 and 7 a.m. and the flues cleaned. They have horizontal smoke connections with two iron stacks 5 feet diameter and 65 feet high. One man per shift easily handles the boilers. Two similar 80 h.p. boilers originally stood at the mouth of the mule tunnel driving a No. 5 Gates crusher. These were installed beside the present crusher house and were intended to supply steam to the hoisting engine and crusher engine which are now run by air, but owing to the fact that electric power is to be introduced in the near future, they will probably never be used for that purpose.

Coal is stored in a large bin just outside the boiler house and brought in in one ton cars. The bin has a capacity of about 200 tons and being situated about 200 feet lower than the railway and at a considerable horizontal distance, the question of transferring the coal from cars to bins presented some difficulty. It was finally solved in a most ingenious manner. An incline railway was built on the ground, the upper half at a 10 degree slope and the lower, 30 degrees, the latter section being double tracked. Two old wooden cars were taken and cut down so that the tops would be horizontal when they were on the steepest part of the incline. They were connected by a $\frac{1}{2}$-inch wi e rope which was wound around a drum at the top and so arranged that one car would be at the bins when the other was at the car. The cars were fitted with a self dumping arrangement, a small wheel catching on a horizontal rail releasing a catch and allowing the lower end of the car which was hinged at the top, to swing open and discharge the coal. The drum was fitted

with two brakes so that the speed of the car could be regulated by the loader. The double track was continued a little beyond the middle of the tramway to allow the cars to pass and the switch was so arranged that the cars coming up would automatically throw the switch over so that it would go down on the same side when loaded. It was expected, of course, that the loaded car would be heavy enough on the 10 degree slope to pull the empty one up the steeper, but it was found that not quite enough coal could be placed in it to make this possible. To get over this difficulty the most ingenious part of the whole scheme was arranged. A long narrow box was filled with scrap iron and placed upon the top of the loaded car, iron supports being built up to receive it and keep it horizontal. With this additional load it was found that the car could easily bring the other up. Just at the point reached by the loaded car when the empty one had passed the summit of the heavy grade, a frame work was built on each side of the track just high enough to pick off the box of iron. This is picked up again by the empty car and carried to the top where it is ready to repeat the operation. The whole scheme is exceedingly simple and works to perfection, one man only being required to transfer coal from cars to bin.

Air Compressor and Transmission of Power.—The compressor in use at the Mother Lode, is the largest single compressor in the Boundary country and was supplied by Jas. Cooper & Co., Montreal. It is of the cross compound Corliss type, the air cylinders having Ingersoll valves. The fly wheel weighs 21 tons and the r.p.m. are 72. The compressor is rated at 350 h.p. and compresses 3 200 cubic feet free air per minute to 110 pounds. It has a capacity of 40 drills at sea level and 35 to the Mother Lode elevation, of 3,300 feet. Between the h.p. and L.P. cylinders is a cylindrical intercooler 10 x 5 feet around which water circulates in pipes on its way to the condenser. Metallic packing is used in the steam cylinders and lasts about five years while the waste used in the air cylinders has to be renewed every three months. The compressor is overhauled every Sunday but few repairs are ever necessary, not an hour having ever been lost through breakage of any part of the compressor. Beside the drills, air is used to run the hoist and other power plant about the

mine and hence its actual capacity is only about 15 drills, air reaching them at about 90 lbs. pressure.

The main air tank is placed just outside the compressor house at he entrance to the drainage tunnel on the 200-foot level through which an 8 inch pipe leads the air to another tank of the same size at the 200-foot level shaft station. Thence air is supplied to this level and also to the 300 and a 7 inch pipe leads it up to the 60 foot level and to an 8 x 4 tank at the shaft mouth. From this tank is supplied the crusher engine and hoist and also another receiver of the same size placed behind the hoist house, whence a further distribution is made to the quarry and No. 1 tunnel and also to a similar tank at the mouth of the mule tunnel from which part of the 60-foot level, the shop and other surface works are supplied.

Shops.—As but little timbering is done in the mine, he carpenters are employed mainly in making repairs to buildings and building new cabins and cottages. The shop contains no special equipment outside of the ordinary carpenter's outfit and a circular saw run by a motor is the only wood working machine on the property. Three men do all the work about the mine.

In the blacksmith shop are two large circular forges, the machine steel sharpener, an emery wheel and a small drilling machine. A feature of the shop is the use of an old machine drill as a power hammer. Four men are required to handle the work in this shop, two sharpening steel and two at general repair work.

The machine shop under the same roof is fairly well equipped as it does all the work required for the smelter as well as for the mine. The machines comprise a lathe with 8 foot bed plate, a drilling machine with a capacity of $\frac{1}{8}$ to $1\frac{1}{2}$ inches, a 6 x 4 foot p'aner, a pipe cutter and threader taking sizes from 1 to 8 inches, an emery wheel, grindstone and smaller equipment. All the machine tools are by the American Tool Works Co., Cincinnati. The power for the machines is supplied by a small 4 h.p. engine. Six men are employed in the shop and on the pipe gang.

Management and Administration.—The mine is under the complete control of the Superintendent, Mr. A. C. Holman, whose ingenuity has solved many difficulties both small and large and

whose economical methods are doing much to keep the mine on its present satisfactory paying basis. The mechanical department is in charge of a master mechanic, a general oversight being had by the mechan cal engineer Mr. George Williams whose time is, however, nearly all taken up by the smelter. The immediate control of the men is in charge of shift bosses, one for each shift in the quarry and underground. The Company has only recently added a surveyor to the staff. The system of keeping time and accounts, while very complete, is simple and requires the attention of only two men, one of whom also acts as store-keeper.

Conditions of Labor.—The rules under which the men are employed are only those necessary to provide for general safety and efficiency, and, being far from stringent, are rigidly enforced. All work is done by day labor, the length of shift being 8 hours underground and 9 hrs on the surface. There is no Sunday work done in the mine and day and night shifts change over every fortnight. The mine is run on "open-shop" principles, although the Western Federation of Miners is the organization to which most of the men belong. There has never been a strike. The men are an exceedingly intelligent body, the foreign element not being present in such a large proportion as in most western camps and as the Company takes excellent care of their welfare, any small difference is easily and speedily adjusted. The change rooms are conceded to be the best in the province, the bunk houses are large, airy and comfortable and the boarding house is run on a principle which leaves no room for complaint and which spares no pains to satisfy the men. The Company has built about thirty good sized cottages, steam heated and electric lighted, which are let to married men and numerous small cabins, also heated and lighted. The Company also runs a well stocked general store for the accommodation of the men and there is a well equipped reading room. Religious services are held every Sunday in the large hall in the boarding house.

Each man pays a dollar a month physician's and hospital fee, and in case of accident or ordinary illness contracted while at work has the care of the Company's doctor. On the whole, the conditions of labor are almost ideal and are in sharp contrast with those in other mining camps in the west.

Future Plans.—A plant to develop electric power at Bonnington

Falls on the Kootenay River is now being installed and a transmission line into the Boundary will be completed before the end of the year. Next year, electric power will be introduced at the Mother Lode. The compressor and crushers will be electrically driven. The removal of the necessity for using so much air for general power will practically double the drill capacity of the compressor and active preparations are at present going on for at least doubling the output. The shaft is to be sunk at least 200 feet deeper without delay and the 200 and 300-foot levels are being cleaned up in preparation for the recommencement of operations on them on an extended scale. The shaft stations are being enlarged and at the 200 and 300-foot station, large pockets are being prepared. On the 60-foot level also several new stopes are being opened. In all probability, also, the quarry will share in the general extension, and it is quite likely that all the ore down to the 200 foot level will be taken out by this method. Such, however, is only a rumor as yet, though the fact that a raise is being run from the 200-foot shaft station to the 60 would seem to lend colour to the rumor.

THE GREENWOOD SMELTER.

Location.—The B. C. Copper Co.'s smelter is situated adjoining the town of Greenwood on an improved elevated flat some 70 acres in extent. Boundary Creek forms the southern boundary of the site and Copper Creek also runs through the property. The distance in a straight line to the Mother Lode is about 2½ miles and the difference in elevation, 850 feet. The main line of the Columbia and Western division of the C.P.R. runs through the grounds.

History.—The Greenwood smelter was designed and erected in 1899-1900 by Paul Johnson, E.M., to handle the ore from the Mother Lode mine. One furnace was blown in February 18th, 1901, and during that year 117,077 tons of ore were smelted. A second furnace was installed in the early part of 1902. For some time the smelter sent its matte away for conversion into blister copper but early in 1904, a complete Bessemerizing plant was installed. In the same year also, electric power was introduced. The present smelter Superintendent is Mr. J. E. McAllister, a

graduate of Toronto University and formerly of the Tennessee Copper Co., Copperhill, Tenn.

Sampling.—The Company owns its own railroad scales and all the cars of ore are weighed before being unloaded. The ore for sampling at the smelter is brought to the upper ore bins, which are six in number. These, at 156 feet elevation, are arranged side by side in parallel lines of three each. Each bin is 50 feet long, the railroad tracks going over the center line of each bin.

Most of the ore is brought to the smelter in dump cars, usually of from 30 to 35 tons capacity. The cars are unloaded by simply opening the two doors in the cars, and the entire contents are dumped into the bin below. When the ore comes in box cars, as it occasionally does, it is unloaded by shovelling into the bin over which the car stands. The ore, after being dumped or unloaded into the bin, is drawn through ore gates 3 feet wide by 2 feet high, into scoop cars travelling on rails. These hold from 1 to $1\frac{1}{4}$ tons of ore each, and are run on a tramway of a 1 per cent. grade to the top floor of the sampling mill. One man is able to handle two of these cars, as when once started they run by gravity. When it is desired to check the railroad scale weight the cars are weighed on a Fairbanks scale and are then pushed to the large hopper of a No. 5 Gates crusher and the contents immediately dumped. Lumps exceeding 11 inches in diameter are broken with sledge hammers to sizes that can be admitted into the 11-inch opening between the corrugated crusher head and the concaves of the crusher. The crusher is set to crush to a size of from 3 to 5 inches, corrugated crusher heads being used. If, as stated, the lumps of ore do not exceed 10 or 11 inches in thickness, there is no delay in passing the material through the crusher, which will then easily crush a ton of ore in from a half to three-quarters of a minute. The crushed material is then spouted down to the first Johnson No. 1 sampler. This sampler makes between 6 and 7 revolutions per minute and cuts out either 10 per cent. or 20 per cent., as desired for the first sample. The rejected 80 or 90 per cent. passes through the rejecting spout into ore bin No. 1, while the sample passes through the sample spout to a No. 2 Gates crusher. The sample is now crushed in this second crusher to a size of from $\frac{3}{4}$ to $1\frac{1}{4}$ inches, and then passes through a No. 2 Johnson sampler. This cuts out three samples for each revolution and makes nine

revolutions per minute. Twenty per cent. is taken for the sample, while the remaining 80 per cent. is rejected to the ore bin No. 1. The sample is now conveyed to the boot of the elevator and from there lifted about 55 feet to the top floor of the sample mill and dumped through a chute to a No. 0 Gates crusher. This reduces the sample to sizes from $\frac{1}{4}$ to $\frac{1}{2}$ inch, and the material is conveyed through a spout to Johnson sampler No. 3. This sampler, making 12 revolutions per minute and cutting three samples for each revolution, again cuts out another one-fifth for the sample. The remaining four-fifths are discharged into ore bin No. 1, while the sample is dropped upon a sloping feed table, which, with a reciprocating motion, feeds the sample to a pair of 10 by 16-inch Reliance rolls which reduce it to an average size of $\frac{1}{8}$ inch. It now passes through a fourth Johnson sampler of the same size as the preceding one (No. 3) and again 20 per cent. is cut out, while the remaining 80 per cent. is dropped into ore bin No. 1. The now final sample is conducted through a spout and an 8-inch pipe to the sample buggy car and conveyed to the quartering plates. It is here cut down and mixed from one to three times, according to the size of the sample desired. The sample is then taken to the sample grinder and reduced quite fine, is again mixed and quartered down on the bucking plates. It is then reduced to a 100-mesh sieve and from this pulp the final sample is taken. Usually three bags are filled and sealed, one for the smelter, one for the ore shipper and a third for umpiring, in case of disagreement of the shipper and smelter assays. The sample mill has at present a capacity for crushing and sampling 500 tons in 12 hours, or 1,000 tons by working double shifts. Everything is done automatically, all the work required being to dump the ore into the big crusher at the top, the sample being discharged to the sample car, and the rejected ore to the sample mill ore bin, without further handling. Power is supplied by a 100 h.p. motor. When the mill is running at full capacity two men are required to draw the ore from the upper ore bins into the ore buggies. Two men are required to bring full cars down to the sample mill and to return the empty ones. Two men are required for weighing the ore, dumping it into crusher and in breaking up the big pieces. One man is required to look after the sample mill machinery, and two or three men to bring the ore from the sample mill ore bin to the smelter

mixing bin. When filling the nearest bins only two men are required, while for those further away, three are needed.

By extending the main shaft and installing other sets of crushers, samplers, conveyors, and ore bins, the present sample mill capacity can be doubled or trebled. The dimensions of the present sample mill are 78 feet long, 65 feet wide, and 58 feet high.

Below is given the results of assaying checked samples of various lots, two independent samples, A and B, being taken of each lot. This indicates how nearly two independent samples will come to each other by this system of sampling.

Sample	Size of Lot		Cu. % wet	Assay	
	No. of Lot	Tons		Au. oz.	Ag. oz.
A	1	32	6.6	0.04	1.00
B	1	32	6.4	0.03	1.25
A	2	65	6.10	0.12	1.80
B	2	65	6.15	0.12	1.70
A	3	110	3.85	0.01	2.17
B	3	110	3.80	0.01	2.20
A	4	150	1.70	0.145	0.34
B	4	150	170	0.150	0.33
A	5	27	1.70	0.52	1.30
B	5	27	1.68	0.48	1.39
A	6	32	0.90	0.15	0.41
B	6	32	0.93	0.14	0.42
A	7	60	0.88	0.20	0.45
B	7	60	0.90	0.18	0.44
A	8	17	0.00	0.74	5.60
B	8	17	0.00	0.72	5.62
A	9	30	0.00	0.36	2.00
B	9	30	0.00	0.34	1.90
A	10	110	0.00	0.29	9.70
B	10	110	0.00	0.27	9.60
A	11	17	0.00	0.04	25.70
B	11	17	0.00	0.04	26.40

Ore bins.—The lowest floor of the sample mill building is two feet higher than the top of the lower or smelter mixture ore bins. There are two sets of these bins, each twelve in number in four parallel rows, the whole having a length of 152 feet and a width of 110 feet, under one roof. The bins are 20 feet high. Under them are tracks and ore bin gates to draw out the ores into ore buggies run into the furnace feed floor. These bins give a storage capacity of about 10,000 tons. They are crossed by three parallel railway tracks over which the bulk of the ore from the Mother

Lode, already crushed at the mine and consequently not having to be passed through the smelter sample mill, comes to be dumped direct into the lower bins. This simplifies the handling of the ore from the company's own mine when the different characters of ore from the various stopes are known, and the material being crushed and sorted at the mine, can be dumped in the ore bins right in front of the furnaces and thus sampling and transfer costs from upper ore bins saved.

On the levelled flat, on both sides of the ore bins, is the room and floor space allotted to coke and coal storage, which is large enough to hold several thousand tons if needed.

Blast Furnaces.—The ores are drawn from the smelting mixture bins into cars and brought over the charging scales, there, weighed and adjusted, and then brought on the furnace floor in front of the feed doors where they are charged together with coke and slags into the furnace. The lower part of the blast furnace house is constructed entirely of steel and stone work and the feed floor is of 1 inch cast iron plates. This makes the smelter fireproof against matte explosions which are hard to prevent where liquid matte is dumped or spilled over moist places. The furnace house is 58 feet wide by 45 feet long, 15½ feet to feed floor and 42 feet to peak of roof. At the middle of the north part of the blast furnace building is a double platform elevator, lift capacity 5 000 lbs., to take up cars of slag or matte from furnace floor to feed floor.

The furnaces are water-jacketed stack furnaces, the downtake going from 12 feet above feed floor up some 15 feet and then down into the big main flue. They are 42 inches wide by 150 inches long, inside dimensions at tuyeres, of which there are ten at each side, of 3½ inch diameter. The furnaces and all the machinery for the smelting works were furnished by the Edward P. Allis Company of Milwaukee. Slag and matte run together continuously out of the furnace through a trapped spout into a fore-hearth, 6 feet in diameter. The slag runs out into another settler through a spout at the top. Matte is tapped off every four hours and is run into large pots in the converter building and thence to the converters.

Slag Disposal.—Slag runs continuously from a spout at the top of the settler. Originally it dropped into a large granulating trough but owing to the filling of the dumping ground suitable for that purpose it became necessary to abandon the practice of

granulating the slag from the furnaces, so in 1903 a movable slag railway was constructed. The slag is now taken from the blast furnaces in a molten state in large side-dumping pots, tilted by a worm and worm-wheel, each pot having a holding capacity of five tons. They were at first hauled by a steam locomotive with 10 by 14 cylinders, and four drivers of 31 inches diameter and this locomotive is still retained, but a small electric locomotive now does most of the hauling. The gauge of the track is 36 inches and 50 pound rails are used.

Flue Dust.—The flue dust chamber is 12 feet wide by 14 feet high and its length is about 620 feet. It has thick masonry walls, brick-lined in part and arched over with brick. It rises 76 feet 6 inches to the base of a circular brick stack, 121 feet high, the inside diameter of the shaft being 12 feet. This, together with the height gained by running the flue up the hillside, gives an effective draught height of 197 feet 6 inches from the level of the blast furnace charging floor to top of stack. This brick stack was erected in 1903, replacing the steel stack that previously carried off the fumes from the blast furnaces. The dust all accumulates in the horizontal part of the flue. It is drawn off through doors in the side and trammed in small cars to a chamber built at the end of the horizontal part of the flue and directly beneath the briquetting plant where it is dumped into a bin below the ground level. From this bin it is fed automatically by a bucket elevator to the briquetting machinery. This plant consists of a Mould machine, a lime slacker and a conveyor belt and has a capacity of about 100 tons per day. It is run by a 40 h.p. Induction Motor.

Converters.—The Bessemerizing plant was designed and installed early in 1904 by Mr. J. E. McAllister and the product now turned out is 99 per cent. blister copper instead of 45 per cent. copper matte as formerly. This plant consists of two converting stands equipped with five shells of the trough type, 84 inches in diameter and 126 inches long. The converters are tilted by power supplied by a hydraulic accumulator.

For the purpose of conveying the molten matte from the blast furnaces to the converters, and for moving the shells from their stands to the re-lining platform, an electric travelling crane is used. Four motors operate this crane, which is equipped with a main hoist of 40 tons capacity and an auxiliary hoist of ten tons.

The fumes from the converters are taken off by an independent stack, having first passed through steel boxes at the back of the stands, a suitably-shaped steel flue of twenty square feet cross-section, and, finally, a brick chamber of 285 square feet cross-section, in order to collect the flue dust before being conveyed to the stack. The dust is about 75% copper.

The converting plant is housed in a steel building 46 by 90 feet with a lean-to of 60 by 30 eet. At one end of this building is located the relining machinery. The silicious ore used for the linings passes directly from the sampling mill, through a 7 by 10 inch Blake crusher, and a set of 24 inch rolls, into a bin, from which chutes lead to a 6-ft. Carlin mixing pan. The clay used as a bond for the silicious ore of the lining is delivered by similar means into the pan which automatically discharges the mixed product, ready for tamping, in front of the converter shell.

The blast for the converters is furnished by a Nordberg blowing engine with cylinder 40 inch diameter and 42 inch stroke having a capacity of 5,000 cubic feet of air per minute, at 12 lbs. pressure. This compressor is rope driven by means of a 300 H.P. induction motor operating at 2,000 volts.

Power.—Originally steam was used to supply power at the smelter and the plant is still retained to provide against possible failure of electric power. The engine and blower house, 60 feet by 45 feet, contains two No. 7½ Connersville blowers, the high-pressure cylinder of a compound condensing Reynolds-Corliss engine 16 by 35 inch rated at 150 h.p. with 100 lbs. steam pressure, and an electric light dynamo with direct-connected engine. In the adjoining 45 feet by 40 feet boiler room there are three horizontal return tubular boilers 66 inches by 16 feet, each of 100 h.p. and equal to a steam pressure of 130 lbs. Space was left for housing more boilers, but as electric power has been substituted for steam power throughout the works, the earlier intention to double the steam power will not now be carried out.

For the transmission of electricity the B C. Copper Company has built a pole line, with two independent three-phase circuits, to connect with the sub-station of the Cascade Water Power & Light Co., at Phœnix, a distance of four and eight-tenth miles. This line terminates in a brick sub-station containing step-down transformers from 20,000 to 2,000 volts of 100 h.p. capacity.

From this sub-station the alternating current is transmitted at 2,000 volts to the power house in which are located transformers with a further step-down to 550 volts.

A 75 k.w. motor generator furnishes the direct current required for travelling crane and the necessary power for trolley locomotives to be used in the immediate future, a 300 h.p. motor, previously referred to, drives the Nordberg compressor, there are two 100 h.p. motors for the two blast furnace rotary blowers and one for the sample mill, a 40 h p. motor drives the converter lining machine, a 20 h.p. motor operates the hydraulic accumulator for tilting the converters, a 15 h.p. motor runs elevators connecting the blast furnace tapping and charging floors, and a 15 h.p. motor the sample grinding machinery. The lighting on the plant and premises is provided for by a series of transformers, each having a capacity of 150 lamps.

Water Supply.—Water for the works is taken from a reservoir formed by a dam across Copper Creek by means of a steel water-pipe line, 8 inches in diameter and 2,600 feet long, placed in the center of a wooden box flume on trestle-work. The box is 2 feet in the clear inside and packed with sawdust, to prevent the freezing of the pipe. The temperature in winter sometimes comes down to 30° below zero, F. The water is delivered at the smelter at a pressure head of 115 feet, and is sufficient for all purposes. While steam power was used at the smelter this main pipe was also connected by means of a 6 inch pipe-line, 500 feet in length with a steam pump, placed below to take the water from the Boundary Creek. This pump had a capacity of 1,200,000 gallons in 24 hours and had its own boilers. This precaution was taken in case any accident should happen to the upper line. To provide against such accidents now, an auxiliary supply is derived from the overflow from the main dam, which is carried in a V flume to a tank holding about a thousand gallons, the location of which is shown on plan E. This tank supplies the water for the hydraulic accumulator and the blast furnace jackets. Any overflow is carried to a pond back of the carpenter shop, whence it may be again pumped to the tank in case of need by a small steam driven pump.

Shops.—The smelter shops require little comment. Recently, however, a new and complete equipment has been ordered.

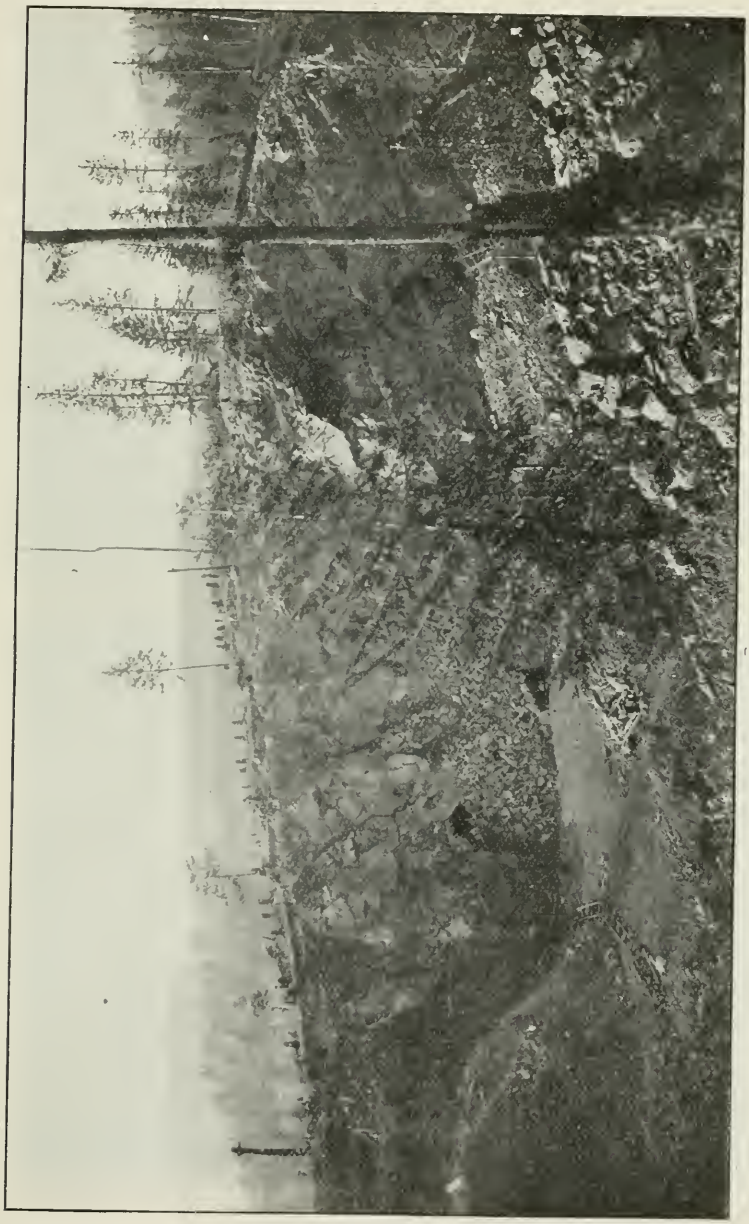
Disposal of Product.—The blister copper is cast into 400

pounds ingots and shipped to the New Jersey refinery. The lowest spur of the three is called the copper spur and runs just back of the converter building to facilitate the shipment of the smelter product.

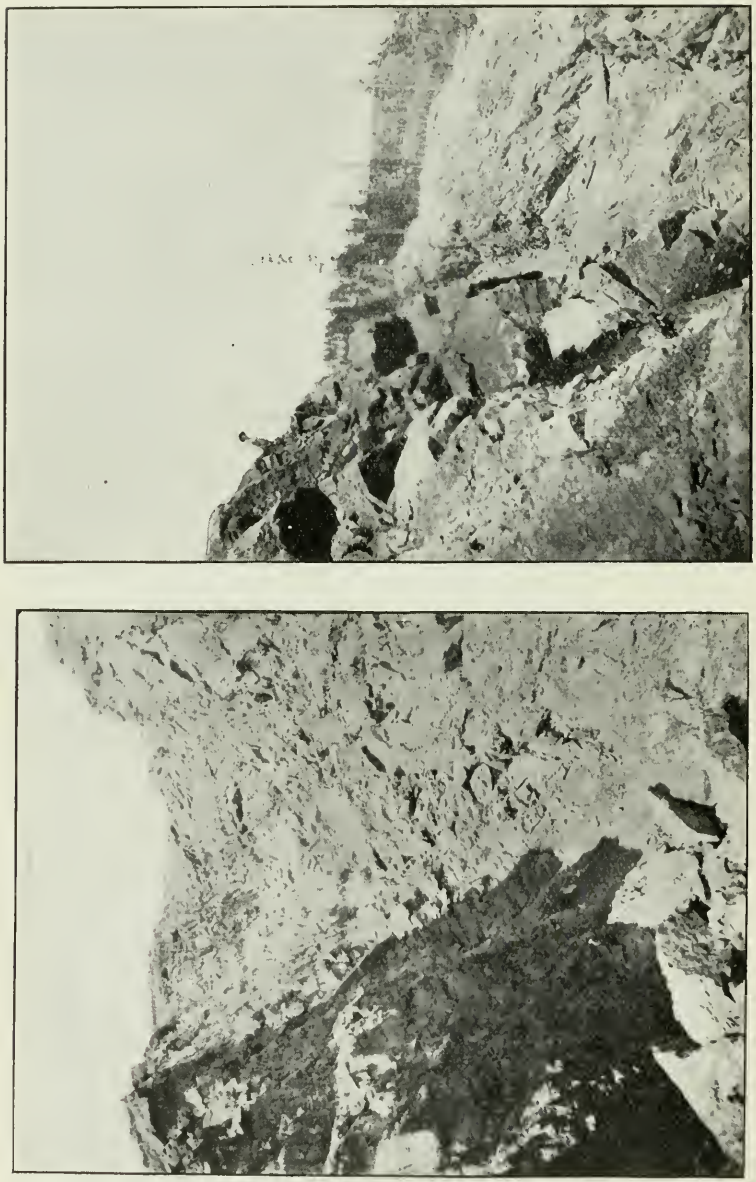
Assaying.—The system of keeping assay records is very complete and every facility is provided for accurate work both in wet and dry methods. There are two large coke furnaces in the furnace room with a total capacity of about 200 cupellations at one time. The wet method room is very completely equipped, a feature being a very ingeniously arranged stand for electrolytic work. The balances are the best obtainable.

The days work consists of:—30–40 ore determinations for silica, lime, iron, and sulphur; 4 slag analyses for silica, lime, iron and copper; 4 matte analyses for copper; 2 blister copper for copper, gold and silver, together with any special ore or coal analyses which need to be made. Two men are kept continuously at work in this department. Since the above description of the smelter was written the plant has been rebuilt, only the Converter department and Sampling mill of the old works remaining: Three huge furnaces having a hearth area of 80 sq. ft. and capacity of 600 tons each per day have been installed together with corresponding changes in power house machinery: the ore bins have been immensely enlarged, the old ones having been torn down.

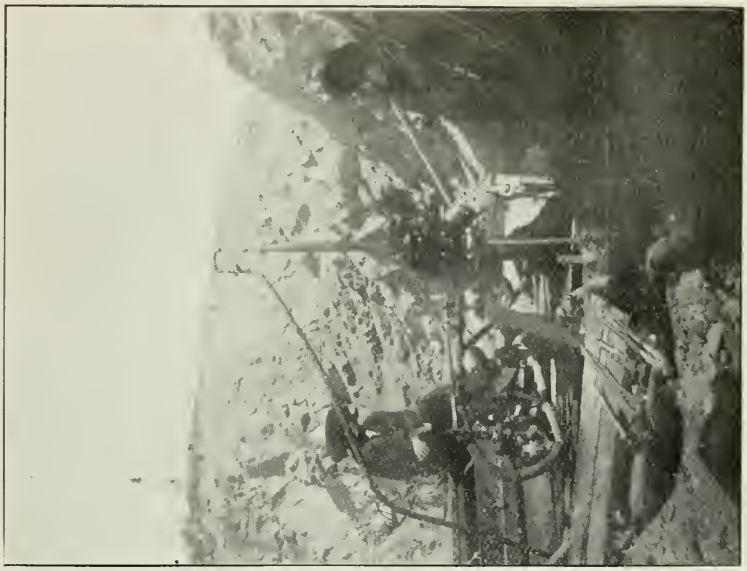
The slag system is also completly changed, a large machine shop installed and many other additions and improvements made, including mechanical charging in place of the old hand feeding.



Early operations in the Quarry at the Mother Lode Mine, Anaconda, B.C.

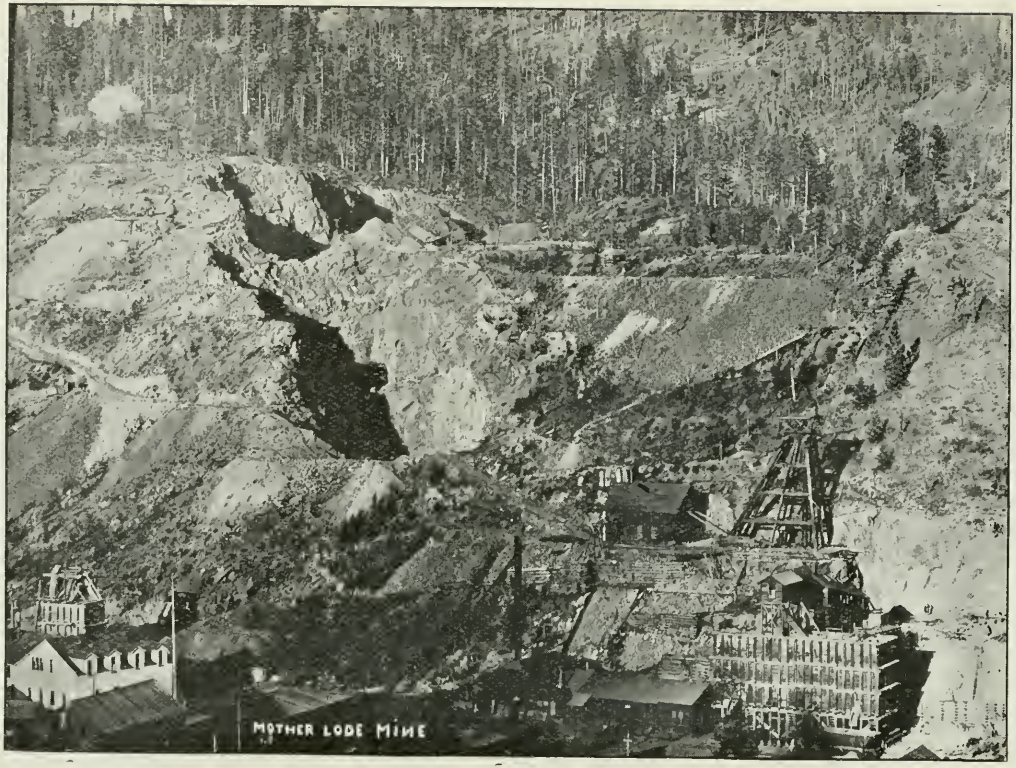


Views of Glory Hole, Mother Lode Mine.



The Diamond Drill operating in the Glory Hole.

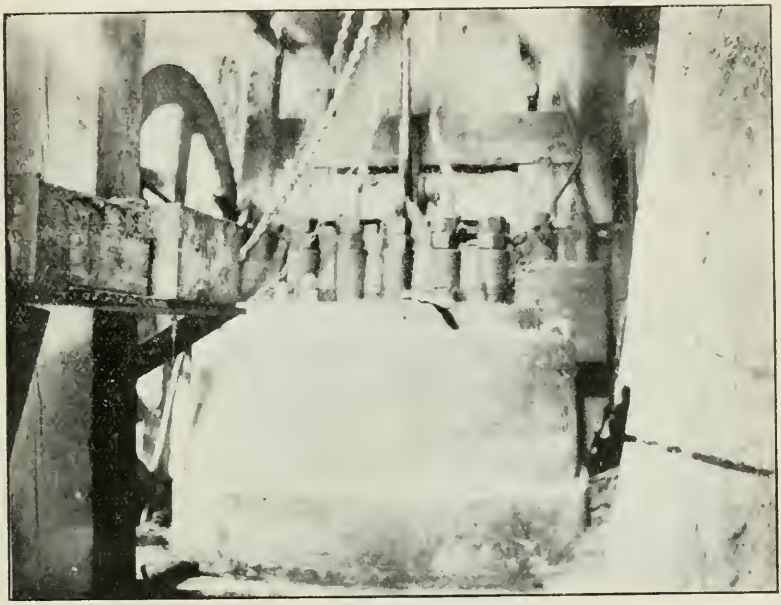
Drilling in the Glory Hole.



General View of the Mine, from a phothgraph taken Aug. 1904. 1 Old Ore-bins and Crusher House. 2 Dining Hall. 3 Change House. 4 Bunk Houses. 5 Shops. 6 Ore Bins. 7 Head Frame & Hoist.

1 Ore Shute to Crushers from Skip, also shown below. 2 Crusher Engine House. 3 Conveyer Belt. 4 Boilers.

A View of the Headframe.

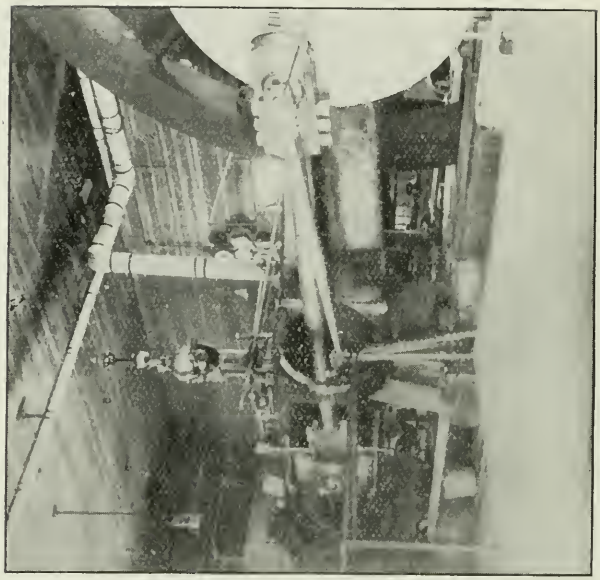


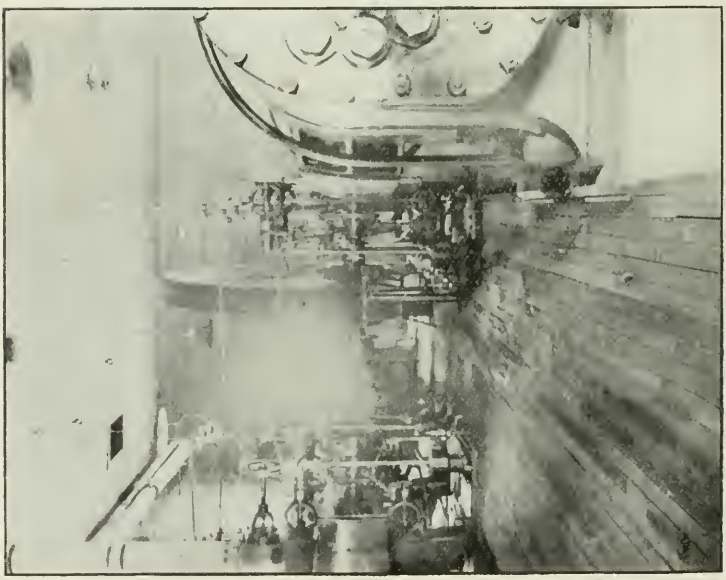
Rear View of Crusher.

1 2

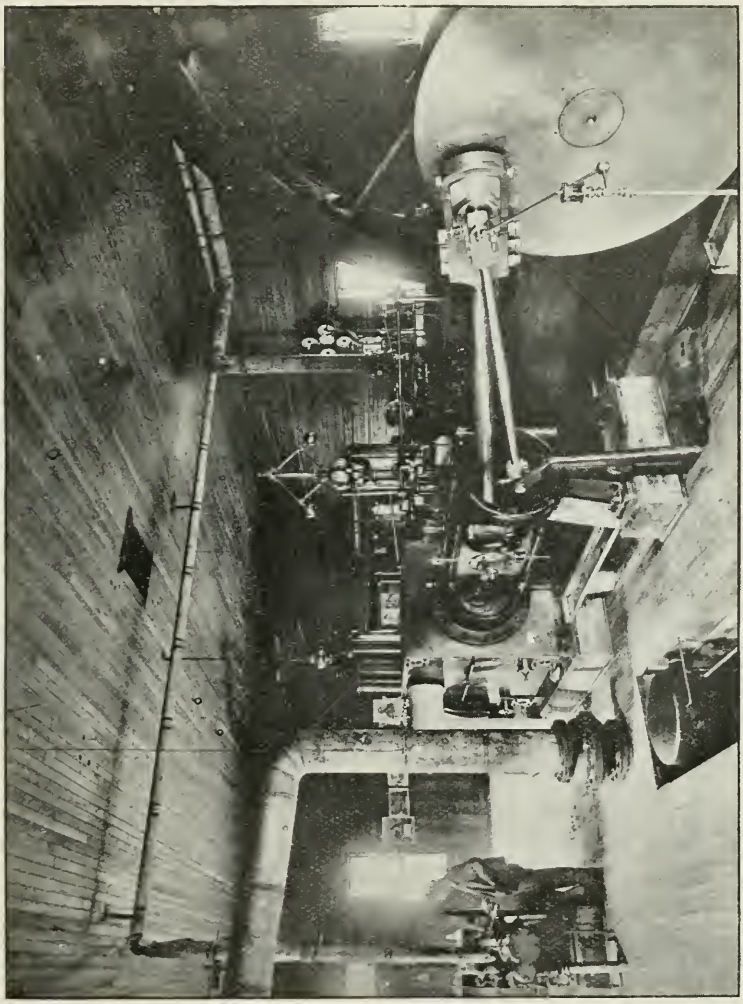
5 4 3

1 Crusher House. 2 Old Picking Shed. 3 Ore Bins.
4 Machine Shop. 5 Blacksmith Shop.





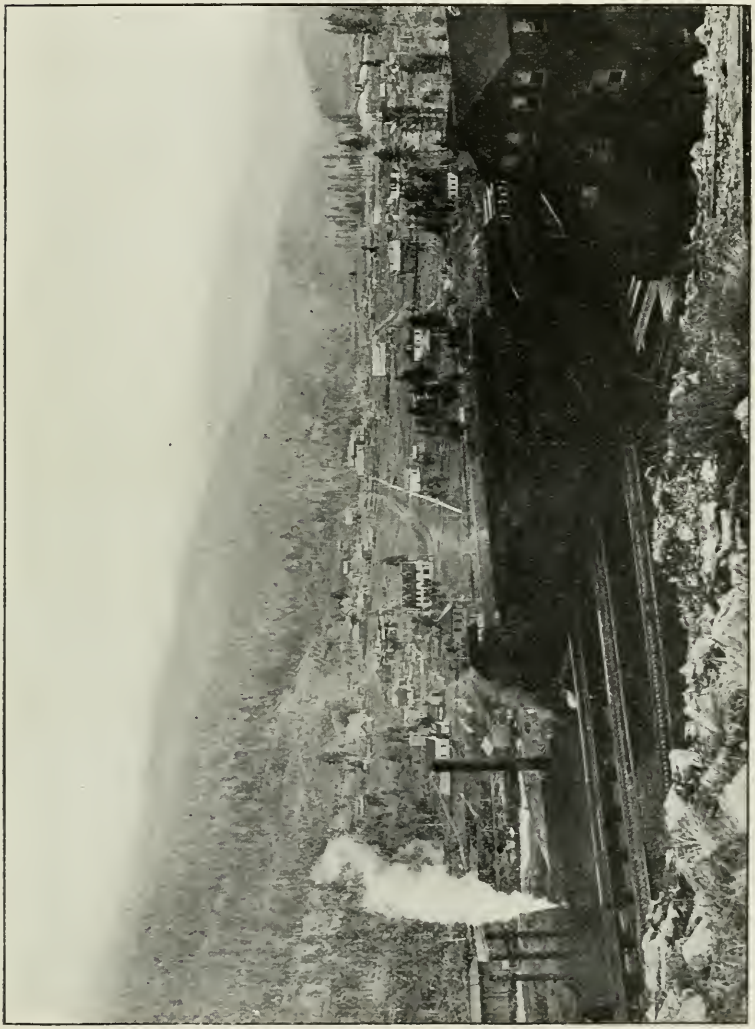
Views of the Compressor.



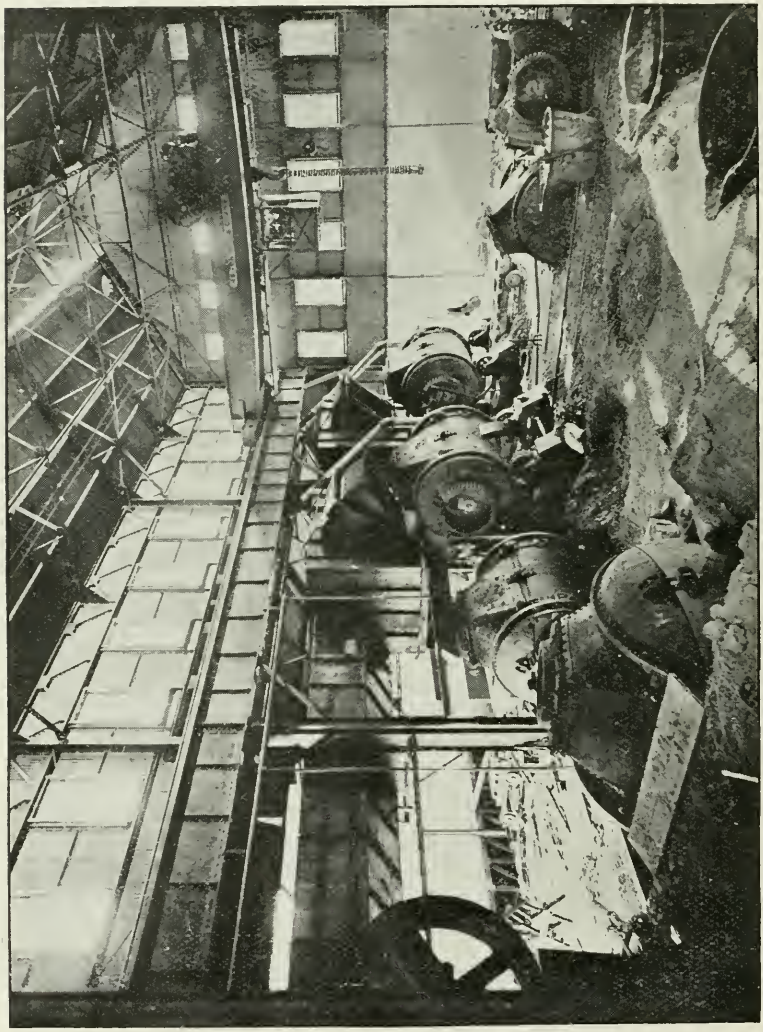
The Mother Lode Compressor.

A General View of the Smelter.

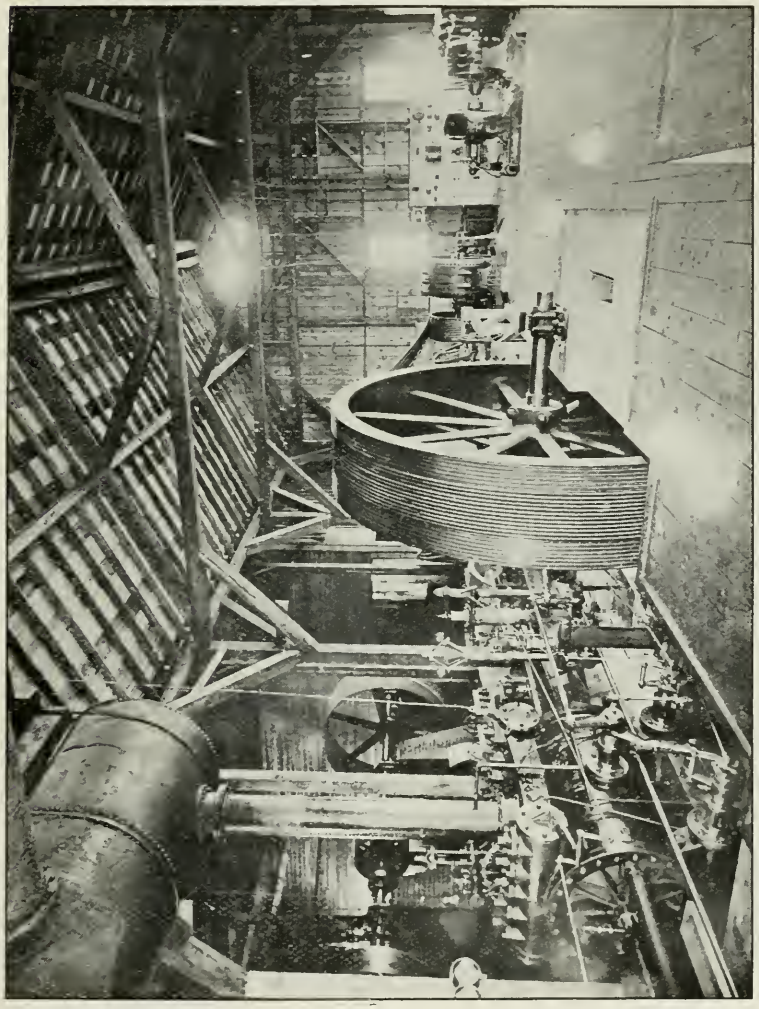
1 Converter Building, showing Flue and Crusher House. 2 Power House.
3 Shops. 4 Storehouse. 5 Briquetting Plant.
6 Copper Spur and Silica Dump.



The Smelter, showing large Ore Bins and Sample Mill.

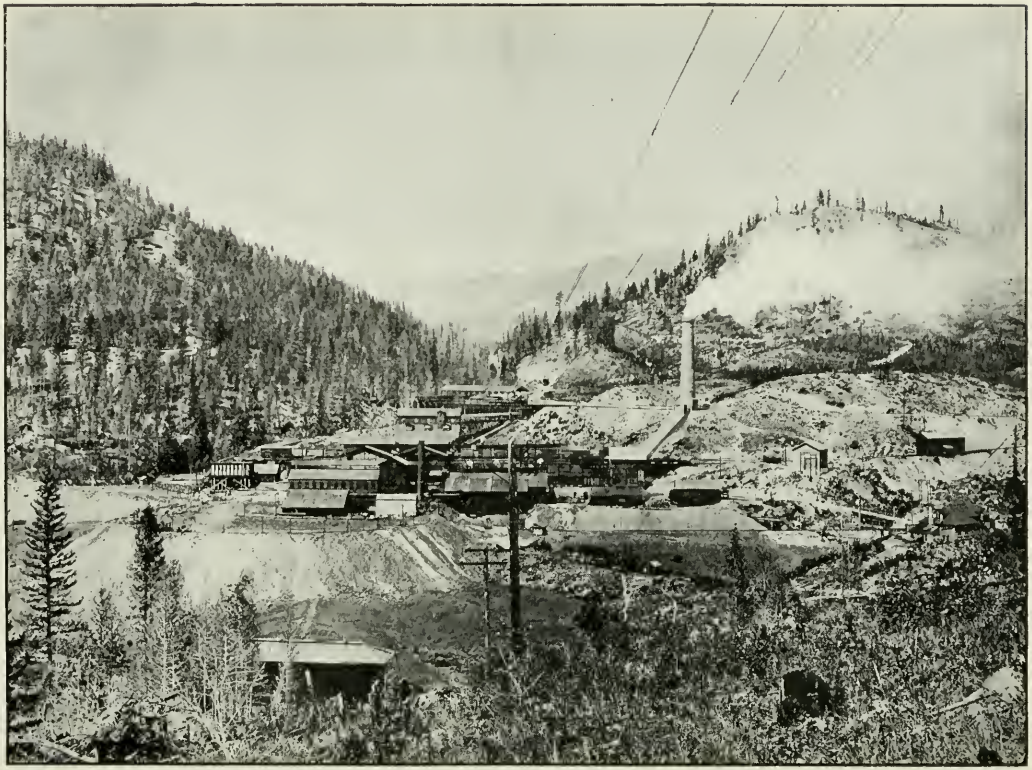


The Converters. The photograph shows two on the stands and one on the relieving platform. The Crane and Dust Flue are also shown.



The Smelter Power House, showing Blowing Engine.

1 2 3



4 5 6 10 9 8 7

General View of Smelter.

1 Mother Lode. 2 Sample Mill. 3 Upper Bins. 4 Pump House and Tank. 5 Converter Building. 6 Slar Car Dumping. 7 Office. 8 Power Sub-station. 9 Railroad Scales. 10 Stack.

THE NORTH SHAFT MINE OF THE SUSQUEHANNA COAL CO., AT NANTICOKE, PA.

By E. E. Winter, McGill University.

The North Shaft Mine, owned by the Susquehanna Coal Co., is situated under the town of Nanticoke, in the county of Luzerne, the fifth Anthracite Mining district of Pennsylvania. It is at the north-eastern end of the Wyoming Valley, and within a few hundred yards of the Susquehanna River, into which the drainage is discharged.

GEOLOGY OF THE DISTRICT.

In the hills in the country the formation most usually met with, on the surface, is the Pottsville conglomerate, the white quartz pebbles of which present the appearance of snow when viewed from a distance. The rocks are nearly all Devonian and Carboniferous.

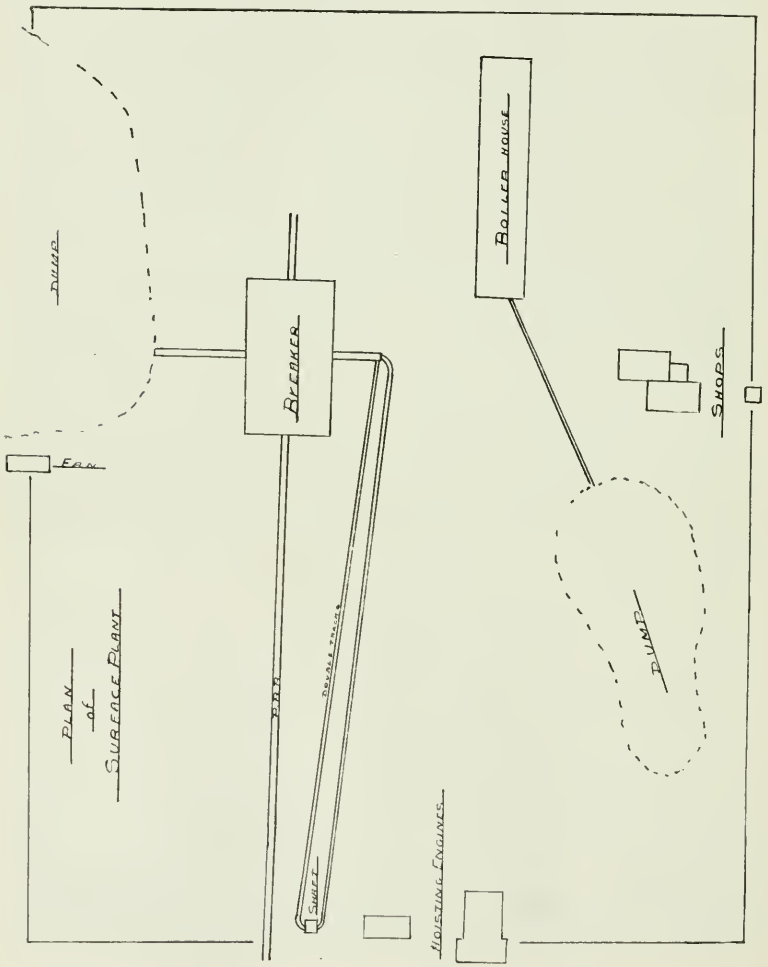
In the broad middle part of the Wyoming Valley, the coal seams lie nearly horizontal, with gentle, open folds, here and there. On the other hand, in the narrow contracted ends of the valley, the strata are extremely contorted and faulted. This makes the operation of mining very difficult and dangerous, since the excessive irregularities of the ground produce a marked increase in the amount of gas set free. In some places, for instance on No. 6 gangway, the seam assumes a vertical position. There are nine large seams of coal which are being worked, namely, the George, Mills, Hillman, Lance, Cooper, Forge, Irvin, Ross, Red Ash. The first six only are worked in the North Shaft.

The above names are merely local and are different in other camps.

Frequently layers of beautifully crystallized Iron pyrites and quartz are found in the coal seams.

SURFACE PLANT.

The surface plan (1) shows the position and extent of the workings. The Pennsylvania railroad runs through the timber yard, next to the head frame.



BOILER PLANT.

There are 16 Babcock and Wilcox boilers, which are arranged in 8 batteries of 2 boilers each. They have a common hearth to

every battery and are contained in a centralized building 52′ x 258′. Two of the batteries have a common smoke stack 5′ x 42′. Of the rest every battery has a stack 4′ x 40′.

The whole plant represents 4000 h.p. The steam pressure carried is 175 lbs. per sq. in.

Feed-water heaters are used. The steam for the heating is got from the exhaust of the breaker and hoisting engines. The coils discharge the steam at the bottom of the tanks, thus compelling it to rise through the water. There is one tank to every battery.

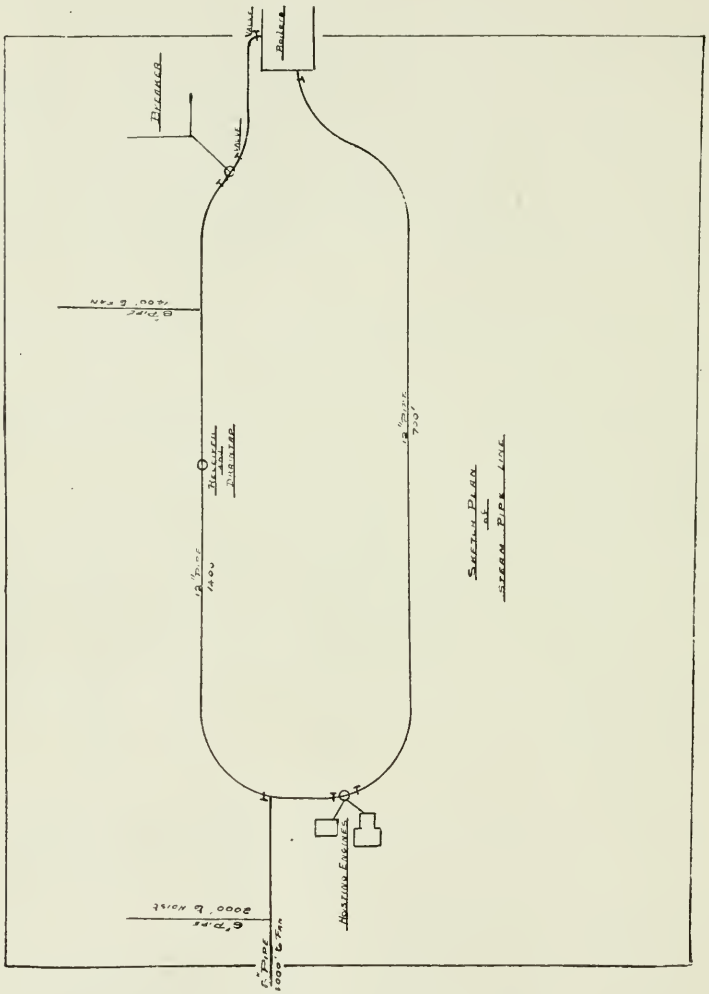
The draught pressure is obtained by a 9′ an and also by steam blowers.

The fuel used is No. 9 anthracite coal or No. 3 Buckwheat as it is sometimes called. In front of every furnace is a trap door in the floor of the building and the ashes are raked through this directly into railway cars beneath and carried away.

The steam from all of the boilers is carried off by a 12″ pipe line or dome. This is carried on a plate, which works on steel rails, mounted on steel I-beams to allow for expansion. The delivery pipes (and all the steam pipes) are bowed instead of jointed. The valve is situated on the dome, because, on shutting down, it is found that water collects in the bow. This water is drawn out by taps before the valve is opened. Were this water sent on to the engines it would result in a cylinder head being blown out by "water hammer."

In order to bring the fuel to the boilers more easily and quickly, two conveyers are in course of construction. One will run from the breaker to the boiler-house and the other, along the length of the boiler-house and at right angles to the first, and distribute the fuel to every boiler.

On every boiler there is a whistle which blows automatically when water is required for the boiler, and again when the supply is sufficient. The boilers are fed by pumps. The drawing of the pipe line shows that in case of a break, by shutting two valves, the whole plant could still be supplied with steam.



HEAD-FRAME.

The structure is of steel with four sheaves, two hoisting from he North Shaft and two from the South. The South Shaft is 00 feet deeper than the North, but the sheaves and all other parts re of the same size.

HOISTING ENGINES.

The engines were made by the Vulcan Iron Works, Wilkesbarre, Pa. They are direct-acting, simple, duplex, non-condensing engines. The drums are conical, the smaller diam. being 10 feet and the larger 14½ feet. The length of the face is 4′ 10″. The cylinders are 30″ x 72″.

The engines work counter-balanced. When running full the valve cuts off at ¾ stroke. The steam is shut off 150 feet from the top. Steam pressure is 100 lbs. per sq. in. The depth of the shaft is 600 feet and a round trip takes 21 secs. The average output is 500 cars per day of 10 hours.

The brakes are never used except to hold the cage at one of the intermediate levels.

The rope is a 3″ crucible-cast steel rope, with a hempen core and 19 wires to the strand. Before being bent on, it was thoroughly well oiled and greased to preserve the interior from the effects of the water. While in use it is continually oiled. It is inspected every day. With good treatment a rope will last for 8 to 10 years. A broken rope is never spliced, but a new one put in.

The signals are made by compressed air and there is also telephonic communication between the engine room and the foot of the shaft.

AIR COMPRESSOR.

The compressor used is a 3-stage compressor made by the Norwalk Iron Works Co. of South Norwalk, Conn. The steam cylinder is 20″ x 24″. The low pressure air cylinder is 19″ x 24″, the medium pressure air is 12″ x 24″ and high pressure air is 5½″ x 24″. The air pressures carried are: low 40 lbs., medium 180 lbs. and high pressure 1,000 lbs. The steam pressure is 60 lbs. The engine runs on an average at 85 r.p.m. The valve cuts off at ¾ stroke.

The temperature of the air at the compressor is 285° F. The air cylinders are cooled by water-jackets, into which the water is admitted by a 1½″ pipe. There is no receiver attached to the compressor. The delivery pipe is a 3″ pipe to the foot of the shaft and then a 5″ one. It is ⅓ mile long. There is a difference of pressure of 50 lbs. between the engine house and the end of the line.

The compressor runs the air locomotives. In consequence of there being no receiver, whenever one of locomotives is being charged, the pressure drops 200 lbs.

The 4 cylinders are placed in a line, the same piston rod works in every one. Metallic stuffing is used in the stuffing boxes. Two gallons of oil, and 1 gallon of high pressure oil are used per month.

One man looks after the compressor. There is one water-drip at the end of the pipe line.

FANS.

The mine is ventilated at two Guibal fans, keyed to the same shaft. They were made by the Vulcan Iron Works, Wilkesbarre, Pa., and are belt-driven, the ratio of the belt pulleys being 2-1. The ventilation is on the vacuum principle.

The fans are contained in a house 60′ x 20′, The diameter of each fan is 20 feet and the speed 90 revs. per minute.

The engine which drives the fans is a simple, duplex, non-condensing engine. The cylinders are 20″ x 36″. The valve cuts off at 4″. The engine runs at 45 revs. per min. The diameter of the pulley at the engine is 12 feet and at the fan 6 feet. The steam is brought to the cylinders by two six inch pipes. The exhaust pipe is also a 6″ pipe. The steam pressure is 75 lbs. The belts used are 16-ply belts, 24″ x ½″. The fan runs continuously for about 20 weeks, and when it is stopped, usually in order to replace the packing and the belts.

SHOPS.

The shops comprise a machine and carpenter shop, a blacksmith shop and a locomotive shop.

SURFACE TRANSPORTATION.

The loaded cars run from the mouth of the shaft down a 1 per cent. grade to the breaker. An elevator takes them to the top of the breaker where they are dumped. From here they go back on the elevator and thence to the shaft down an embankment, also on a 1 per cent. grade. The finished product is transported on

the Pennsylvania railroad, the tracks of which pass under the breaker.

Small 15 ton locomotives are used in the yards for carrying off the ashes from the boiler house, and for bringing up timber from the timber yard, which is situated alongside the tracks of the Pennsylvania railroad. There is no storage of coal at the mine. The cost the Company's property only is about 2.26 cts. a ton.

UNDERGROUND METHOD OF MINING.

The method of mining used is known as the room and pillar system.

As will be seen from the accompanying plan of the mine, no pillars have yet been robbed, the first process being still unfinished.

The mining laws require a barrier pillar between two properties. The following is the agreement between the different companies.

AGREEMENT.

First.—That after this date the width of barrier pillar between the workings of adjacent properties is to be five times the thickness of seam mined out from floor to roof at the water drainage level; and that at all points below such level its width shall be equal to the thickness mined out at that point multiplied by one per cent. of the depth below drainage level added to five times the said thickness mined out. Thus: Thickness of workings by 1 per cent. of depth below drainage level + thickness of workings x 5 = width of barrier pillar. And as further illustrated by the attached table of pillars to be left between adjoining mines of different thicknesses of workings at different depths.

Second.—That the water drainage level shall be understood to mean the level at which water would drain off from any abandoned workings, and that where the level is higher in one mine than in an adjoining one, the higher level shall be taken, and where there is but one mine opened it shall determine its drainage level, and if the drainage level of a mine subsequently opened upon adjoining lands is higher, the additional thickness required shall be left by the owner of said mines.

THIRD.—That these thicknesses shall be subject to such modifications as may be deemed advisable under varying conditions of the strata and seams due to proximity of other seams, faulty nature of seam or strata or other conditions shown by the development of the workings.

COAL CUTTING.

The cutting of the coal by hand depends on the presence or absence of a layer of "fire-clay." When the fire-clay is present the coal is undercut for a distance of about 4 feet and a single shot is fired above. The object of the shot is not to throw the coal, in pieces, away from the "breast," but rather to break it off as a large, fractured, mass, when it is again attacked with the picks and broken up to be loaded into cars. In a 24 foot breast it takes $1\frac{3}{4}$ hours to undercut enough for one shot.

The coal cutting is all done by contract. The miner gets $2.16 for each car of coal. Out of this he has to pay all costs, including his labourer or helper who gets 50c. a car. Every pay day 25c. are taken out of the miner's wages for blacksmith work.

No machine cutting is done in the mine. Where hand cutting is impracticable, the coal is simply blasted out.

The cost of a ton of coal loaded on a car at the breast is 72 cts.

BLASTING.

Both black powder and flameless nitroglycerine explosives are used in the mine. The former is used in places where no gas has been detected and the latter in gaseous places. In every case the average charge put in is about ten times the diameter of the hole. In very wet holes, black powder is not used.

The black powder is exploded by squibs, and without the use of a blasting barrel. The tamping used is wet coarse grained dust. After the hole has been tamped right up to the top, the needle, i.e. a big tapered needle, about 5 feet long put in before the tamping, is carefully withdrawn so that no dirt falls into the hole made by it. The squib, which acts much in the same way as a rocket, is then inserted and lighted. It frequently happens that the squib fails owing to the needle not having been carefully withdrawn and the hole being blocked. When this happens an

intermission of 10 minutes is allowed and then the needle is again inserted and another squib put in. Where a nitroglycerine explosive is used, it is sometimes exploded by putting a little black powder on the top and proceeding as above, but more generally by a detonator. This, in turn, is exploded either by a fuse or by an electric exploder. The detonator is usually put in the middle of the charge. It is filled with fulminate of mercury. This is exploded, in the case of the fuse, by a direct spark, and in the case of the electric exploder by the heating up of a piece of platinum wire by a current obtained from a storage battery, or from some magneto-machine by pulling up or depressing a handle.

The powder used is giant powder, and meteor dynamite is now being tried. It is found that one keg of powder, 25 lbs. will break down 30 tons of coal.

No volley firing is done in the coal.

TIMBERING.

The character of the roof varies considerably in different parts of the mine. If the roof is of hard sandstone, timbering is unnecessary. In the shales and slates, on the other hand, very heavy timbering is needed. Wherever the seam is vertical or pitches very heavily, falls and crushes are of frequent occurrence.

In the rooms, the roof is supported simply by "props," from 6″ to 8″ in diameter.

In the gangways, sets, consisting of two legs and a collar, are used. In gangways, 10 feet wide, "medium" timber is used, i.e. timber 8″ x 11″ in diameter. In the large 15 feet gangways, "large" timber, from 12″ to 24″ in diameter, is used. All timber is cut underground. In "standing" the props, a hitch is cut in the floor with a pick, and the prop is wedged in at the root by a large wedge or "cap-piece."

In the gangways the hitches are more difficult to cut. It is necessary for the leg to stand on perfectly solid ground, and any overlying "loose" has to be picked or blasted away. In the shales and slates, it is often possible, by taking advantage of the stratification, to obtain a hitch with iron wedges alone. The legs, when in position, slope inwards at about 80°. The set is "lagged" to the two adjoining sets above and at the sides. The 'agging at the top

is wedged tight against the roof. The lagging at the sides is wedged against the "ribs" with rock. The method of putting the set in is to prop the legs up in front and secure each to an adjoining set by a "lashing-board," and then lift the collar on one end at a time.

The shaft is timbered with square sets.

A gang of timbermen can put in 75 props in one shift, 3 small sets in a day of 10 hours, and one large set in two days. 10 yards gob-walling can be set up in one day.

The cost of timbering the mine is roughly 11.95 cts. per ton of coal mined. It is made up of labour 5.96 cts. per ton of coal and material $5.99 per ton of coal.

UNDERGROUND TRANSPORTATION.

The coal is loaded directly into the cars at the face, no "boney" being picked out except from the layer of large pieces on the top of the car. The little waste that there is, is thrown between the ties for the mules to walk on. The cars have to be loaded 6 inches higher than the level of the top. To test this there is a guage hung in the breaker and if the cars do not scrape against this along the whole length and width, the "docking-boss" calls it $\frac{3}{4}$ of a car. Where the cars cannot be run out of the rooms by gravity, a mule pulls each car out to the counter where a "trip" is made up. For a two-mule team a trip consists of four cars, for a three-mule team, of six cars.

The coal from the Cooper seam is hauled directly out to the foot of the shaft. A round trip takes about one hour, the distance is $1\frac{3}{4}$ miles.

The coal on No. 6 gangway is hauled to the foot of No. 9 slope. The slope is 1,150 feet long at an angle of 20°. Up this it is hauled by an engine situated on the surface, the rope coming down through a bore hole. A round trip takes three hours and the distance is three miles including the distance from the slope to the shaft. The engine for this slope is not shown in the surface plan, being situated nearly a mile away in a wheat field.

The engine is a simple, duplex, non-condensing engine. The cylinders are 28″ x 48″. There is one large conical drum with an 18 ft. face. The drum is 7′ 3″ at the small end and 9′ 3″ at the

large. The rope is $1\frac{3}{8}''$ in diameter. The speed of hoisting is 950 ft. in 7 secs. There are usually 50 trips of 3 cars each in a day..

The grade of the tracks wherever possible is $\frac{1}{2}\%$. If the seam pitches at from 3.5° to 15° a double track is put in and the loaded cars going down pull the empty ones up. The rail used weighs 30 lbs.

The track men are paid $1.32 per day.

The total cost of underground transportation, including hoisting, is roughly 21.7 cts. per ton of coal.

VENTILATION.

In the plan of the mine the course of the air is shown by arrows, and all air-bridges, doors and air shafts are marked.

The mining laws of Pennsylvania demand 200 cubic feet of air per minute for every person working in a mine. It also provides that the velocity of the air, as determined by an anemometer, shall not exceed 450 lineal feet per minute, except in the main inlet or outlet air ways. These laws are rigorously observed. The normal occurrence of fire-damp is considerably below 1% in the outlet airways, but in the vicinity of blowers it occurs in explosive quantities. At from $6\frac{1}{2}\%$ to 7% the gas will explode but not below this. A "fire-boss" goes into the mine before the shift comes down and examines all the working places. No man is allowed in the mine until the "fire-boss" report is handed in, and then every man is cautioned if gas is found in his place. The gas is detected by the blue "cap" which forms over the flame of the Davey lamp. The lamp will not detect below $2\frac{1}{2}\%$. Being lighter the air the gas is always found at the highest point of the roof.

The mine being well supplied with air there is no spontaneous combustion of slack. Fires, in general, are of very rare occurrence. When fires have occurred, they have been put out by jets of water, with which the mine is well supplied, and by brushing with blankets or their equivalent.

LIGHTING.

The fire-bosses and miners carry all-guage Davy lamps, while laborers and helpers carry glass Clanny lamps. Naked lights

may only be used in the immediate vicinity of the shaft. Lard oil is burnt in the safety lamps, each lamp taking about 1 gal. per month.

UNDERGROUND PUMPING.

There is a large Jeansville pump at the bottom of the shaft, which pumps its water to the surface, and another pump, halfway up the shaft, draining the Hillmian seam. The total cost of pumping water out of the mine is 5.14 cts. per ton of coal. The total underground expenses are $1.50 per ton.

PROSPECTING DRILLS.

(By Wallace Dickson, McGill University, Montreal.)

In the development of mineral property for coal or ore, one of the most important considerations is the preliminary prospecting by which the exact position, extent, thickness and value of the mineral deposits are ascertained. This prospecting may be done by actual shaft sinking or drifting; but as such work is very costly deep drilling is often resorted to. This deep drilling may be done by either churn drill or rotary machines such as the Calyx or Diamond drill. The churn drill method is relatively cheap but can be utilized on vertical holes only; it is also unsatisfactory when exact records of distance are wanted, and is absolutely useless in cases where values must be determined by accurate assays.

The Calyx drill is similar in all general parts to the diamond drill. Both consist of three parts:—the drilling and feed apparatus, the hoisting apparatus and the motor. These parts, although comprised in one machine, are yet distinct, and each can be operated independently of the other. The machine is mounted on a cast-iron base plate, bolted to a wooden frame. The smaller machines are frequently manufactured without the drum and are mounted between two vertical columns which can be attached to a wooden frame. In a mine, the columns are placed between the back and sill of the drift and jacked firmly in place.

The Davis Calyx drill is a recent machine made on the same principle as a diamond drill but arranged to use steel cutting tools in place of diamonds. It cuts a larger core hole than is commonly cut with diamonds; and besides being decidedly cheaper than the diamond drill has proved quite satisfactory to operate in soft and medium rock. It can, moreover, be used on moderately hard rock by using chilled iron shot with the cutter, but its maximum utility is found in drilling in soft rock. The diamond drill is, however, used in nearly all works in this country where hard or moderately hard rock is encountered.

The Davis drill will drill on an average from twelve to fifteen feet a day in soft rock. Mr. Davis affirms that two hundred feet of hard, flint rock may be drilled with $3.10 worth of shot; but in practice in this country it has been found that in hard rock, the strain on the rods and machine is so great and irregular that different parts are constantly breaking, thus causing delays and making the expenses of drilling as high as if diamonds had been used.

The diamond drill is said to have been invented by Mr. M. C. Bullock who bored his first hole in 1870. The drill has proved very satisfactory, being perfectly reliable and capable of drilling in any strata, and at any angle. The principal manufacturers of diamond drills are the Sullivan Machine Co., owning the original Bullock patents and others; and the "Standard Diamond Drill Co.," also controlling several good patents. The drills of these companies are similar in all general respects. Some are fed by hydraulic pressure others by a screw. The drills are made to be operated by hand, horse or steam power, compressed air, or electricity. The manufacturing companies and smaller companies either sell the drills outright or do drilling on contract. In the latter case the work is guaranteed.

Each standard type of drill is rated by the maker in accordance with the depth to which it can be expected to bore successfully under average conditions. Each grade of machine is given a letter or two letters as "P" or "CN" and a few have names such as "Beauty," "Champion" etc. The Sullivan and Standard Companies each manufacture a one mile machine. The deepest hole drilled, up to April, 1905, was at Springs, east of Johannesburg, South Africa, the depth being 5,582 feet. A Sullivan size "P" drill was used with "N" rods (2-inch-core) for the first 1,000 feet, and "B" rods (1⅞ inch-core) for the remainder.

The distance drilled per shift in a soft rock is sometimes as much as thirty to forty feet (working 8 hours) with a ten foot core-barrel; in hard pan, hard enough to make core, or in ground with a mud bit, fifty feet is not uncommon, (working ten hours); but in hard rock, an average, for six months was 10.5 feet per shift (8 hours) made in the War Eagle Mine, Rossland, with 1⅞ inch-core. In Le Roi Mine, Rossland, little better than 15 feet was the average for two months with 15-16 inch core.

The cost of drilling varies greatly. The companies that drill

on contract in the coal country, Illinois, contract for $3.00 per foot and furnish all the requirements of the drill and hand the core to the owner. Knight and Stone of Spokane, who drill in Le Roi Mine, are paid $2.75 per foot, the mine supplying the power and water, the depth being limited to 500 feet. The cheapest drilling in the War Eagle Mine was $1.37 per foot; the average was $1.60 per foot, everything in connection with the machine being taken into account, and the mine operating their own machine. Over 2,600 feet was drilled in Ontario, under Government auspices at a cost of $0.98 per foot. At Sutter Creek, Cal., 4,136 feet was drilled, the average cost being as follows:—Labor, $0.4 ; carbons, $0.16; other supplies, $0.04; depreciation of drill, $0.053; total, $0.673. These figures, however, do not include the cost of power for the drill; and the diamond drill, boring a hole an inch and a half in diameter and capable of drilling a hole 600 feet deep, requires about 10 h.p. In diamond drilling, the deeper the hole, beyond say, 500 feet, the greater, naturally, the cost per foot. The price per foot depends entirely on the location and can be easily estimated in any case. The salary of a diamond setter, in Western Canada and in the Western States, is $150.00 per month; in any foreign country $200.00 and expenses. In the Mississippi Valley, the runner is paid $75.00; in Western Canada and the States $100.00 and expenses, or $4.00 a shift, and in a foreign country $150.00 and expenses. The runner's help commands $45.00 in the Mississippi Valley, and $3.00 a shift in Western Canada and the States. In many cases the setter is also a runner and his pay is $50.00 less than a regular setter. The price of carbons per karat, divided by a hundred, will give roughly the price of carbons used per foot in hard rock. The price of power and water is altogether a local consideration, the nature of the rock, and the quantity of wash, are also important factors. In the Transvaal the cost of drilling has, until now, averaged over $10.00 per foot.

The diamond drill is often used for special work. In Butte, Montana, for instance large holes of six inches are bored to carry water into old stopes to extinguish mine fires. In other localities similar holes are bored to run in tailings to some old underground workings. The largest core ever cut with a diamond drill was in a special case for the Capitol Building at Springfield, Illinois.

The core measured $22\frac{5}{8}$ inches in diameter by 4 feet long, and was taken from a 24-inch hole, 120 such pieces were cut from solid cubes of limestone.

An experienced runner can tell exactly what kind of material he is boring, and what the bit is doing; if in soft rock, the increased speed of the machine and the lower reading of pressure affords him the information. If the bit is blocked and grinding the core, the amount of borings increase. To get the best results in soft rock a fast feed is needed, and little water. In very soft rock such as calcite, 200 turns to the inch should be used and a minimum of water; in fact, the only way to make core in very soft rock is to turn off the water for about a second, then on for two seconds and off again and so on, keeping a very close watch all the while on the pressure and the speed of the machine so as to know when the seam has been traversed.

The amount of water used varies greatly; with some runners, it is as low as thirty-five gallons in soft rock, and but little more in hard rock. Others use as much as eighty-five gallons an hour in hard rock and a little less in soft rock. The less water used the less the chance of grinding the core; but there is increased danger of burning the bit. When much water is used drilling proceeds rapidly but the main part of the core is ground away and lost. The careful runner using less water does not drill as rapidly but secures all the core. He, moreover, seldom or never breaks a diamond while the runner using much water and always in a hurry, has frequently a broken diamond for his pains. On the other hand it is possible to err in the contrary direction, and "running dry" spells also disaster, since a bit burns almost instantly if not kept wet and cool. When a bit dries it heats and expands, and if in consequence of the pressure the bit does not become red hot, it will simply jam and the machine will either stop or the rods will break at some point. There are several reasons for the water failing to flow round the bit, the most common being the stopping of the pump, but a rod may split or even break and telescope. When drilling, it is a common occurrence to strike water-seams. Some of these will send out a great deal of water while others will take all the water that is pumped in, without any of it reaching the collar of the hole. Other streams act as a sump and hold all the water that is pumped, coming out with a rush when the rods

are withdrawn. If a rod should split and telescope in such holes, it is very difficult to get any indication of the fact and only very experienced runners can detect it and pull the rods before the bit burns. Water has been known to come out of holes with such force as to require three men to place the core-barrel in the hole. In drilling a down-hole, it is not sufficient to keep the hole full of water to prevent the bit from burning, for, unless the flow has force enough to keep the borings out of the way, the bit will block the hole and burn almost as fast as on a dry hole. Old runners say the best thing to do with a burnt bit, is to keep it moving. This is done by always having the hoisting-rope ready so that it may be hooked on to the water-swivel. The record, as far as has been ascertained for burnt bits, was made in Le Roi Mine, Rossland; when the bit, the core-shell and a foot and a half of the core-barrel were doubled up before the runner realized the fact.

The diamonds are not broken as a rule in a burnt bit; but it is difficult to get the diamonds out of the metal without breaking them; sometimes the diamonds are sawed out, or all the metal possible is cut away from about the diamonds and the remainder put in hydrochloric acid which eats the metal and leaves the diamonds unhurt.

The following is a description of an ordinary day's work for a runner and helper. The work done was on a "Champion" machine on a flat hole in a mine, the depth being about 200 feet.

The runner on first reporting to the setter, receives a bit. The helper puts some candles in the core box. The two proceed to the drill. A shallow pan is placed in a box at the collar of the hole to catch the borings. The helper holds the core-barrel with a pair of tongs while the runner screws the bit on, taking great care not to let the tongs come near the carbons. Crude vaseline is then rubbed all over the core-barrel and a little is put in the bit and it is placed in the hole, while the helper greases all the rods with the exception of two feet from either end. A handful of waste is always used while handling the rods and core-barrel. The runner now holds the core-barrel with one hand and places the first rod up to it while the helper screws it on, and pushes it in and so on for the other rods; it soon becomes so hard that the runner has to use his puller; a few more are added and then the helper uses his puller. A puller is an iron bar 18 inches long with a square jaw

at right angles to the handle, the jaw fitting loosely on the rods. After say 100 feet of rods have been added, the friction becomes so great that the rods must be pulled in by the machine. This is done by passing the hoisting-rope through a block fastened to an eye-bolt near the collar, putting the hook of the rope in the rod and then turning on the air. Sometimes a small cave is met, the engine is not strong enough to force the bit past, so the rope is unhooked, the drum put out of gear, the swivel-head swung into place and the rods connected. If in a dry hole, the water has also to be connected and pump started; but the cave usually occurs where the water is coming in; drilling is then proceeded with, in the fastest feed. The caves vary in length, but are usually half an inch long, that is to say they seldom consist of more than one or two small fragments. When the cave is past, the machine is got ready for pulling rods. The bit sometimes becomes so tight that the machine cannot move it, but by turning the rods a little to the right, by means of the tongs, the difficulty is often overcome. When, however, it is impossible to move them forward, they are withdrawn to where the tight place started, the machine is connected for drilling, and the tight place is reamed out. To do this, water should always be used; but if reaming has to be done several times before the bit is on bottom, the runner is tempted to neglect this precaution. When, at last, the bottom of the hole is nearly reached the last rod will either go in or remain partly out of the hole; a five foot and a two foot length are kept close at hand to be added. It is the runners' aim to make the connection from the main-rods to the swivel-rods as close to the machine as possible. The point on the rods that will be at the collar, is marked and brought up slowly so that the bit will not receive any jar, for there is danger of there being a short piece of core left in the hole. The last few inches are generally pushed in by hand, the machine is connected, oiled, the lubricators filled with cylinder oil, the pump is then turned on at almost full speed till the water comes out at the collar; it it then partly turned off and the amount of water regulated by an air-valve behind the suction. The machine is then started and the feed adjusted to suit the character of the work. With a new bit 400 revolutions per inch is the best feed for hard rock; this, with the machine at 280 revolutions per minute, takes about one hour to drill two feet. When the screw

is run in, the machine is stopped, the chuck-bolt loosened, the feed placed on a blank, the power turned on and the screw run back in less than half a minute, the feed put back on the 400, chuck tightened, and the machine is ready to start again. The runner stands near the collar and watches the water, the pressure, and listens to the speed of the engine. The helper watches the pump. If the water changes colour from a light to a black, it is probable that an ore seam is struck, the machine is stopped, a sample taken, the pan washed out, the rods carefully measured and the machine started. When the ore has been passed or different colour observed, another sample is taken and the width of the ore body carefully noted. The runner endeavours to maintain the speed as uniform as possible. Should the rods vibrate, a higher speed is required; if all the power is on and rods still vibrating, a slower feed is needed. Sometimes the fast feed will stop the vibration if the pressure be released. In changing ground the bit generally blocks, and the machine must be stopped. This block is sometimes broken by giving the rods two turns to the left and then forward till free. If this does not clear the bit, the rods are withdrawn. The machine is used to pull the rods out by passing the hoisting-rope around a pulley of the machine and hooking it into the "comealong." This fits loosely over the rods like a collar and when the rope tightens, it presses a clamp against the rods. The runner starts or breaks the rods with the tongs and the helper finishes unscrewing them. The breaks are made, at the same joints, each time the coupling being always taken off the end next the collar, except the last, then the coupling is left on the core-barrel, the bit removed, the core-barrel cleaned out and the core placed in a triangular trough in the same order as it was in the hole. The bit and core-barrel are then thoroughly examined, connected and placed in the hole as before. The core is washed and placed in core-box in the same order. The length of each pull is marked on a little square block and put in at the end of each core. Two hundred feet of rods can be pulled out and replaced in thirty-five minutes, breaking the rods every ten feet. When core is left in the hole, a blank bit is put on instead of the carbon one and sent after the core. A blank bit is an old bit that has had the carbons removed and the inside filed, chisel-fashion. When the bit is on bottom, the machine is operated at a high rate, without water, so

as to turn in the edges as in a burnt bit. Before pulling,the first rod is measnred to find how much it projects from the collar, and when it is the last pull for the shift, a note giving this and other information is carefully made. A sample is then taken and the pan-washed out. The core, the bit and the samples are brought to the office, the samples are placed in shallow pans to dry, and when dry, put into envelopes with the date, number of hole, the distance at commencement and distance at end of shift noted. The core is placed in long shallow trays, inspected and sections removed for assay. Some of the borings are also occasionally assayed. After completing his work, the runner must make out a full report of the operation. This report shows, the date, number of hole, depth at the commencement and also at the finish; if ore has been found, how many feet; what kind of rock; the actual drill time, the delays and what occasioned them, and finally, any further remarks he may see fit to make. These records with the assay returns and other information are used by the survey staff in making up the mine maps and assay p ans.

It is a well known fact that long drill holes are seldom straight, and that the tendency to get out of line is greater in flat or inclined holes than in vertical ones. This difficulty of drifting, can be partly overcome by using rods which are as snug a fit as possible in the hole. The drift of holes is seldom serious unless the length exceeds 500 feet and therefore the ordinary prospecting holes in mines may be taken as straight even when no special precautions have been taken in drilling. The shallow holes are surveyed by placing a straight rod in the hole, with the end projecting out, and held in line of the bore, while the surveyor takes the bearing and the dip. In the case of deep holes the drift cannot be neglected and this is particularly true in the case of drilling in South Africa, where many of the holes near Johannesburg have exceeded 4,000 feet and some have nearly reached 6,000, several of these deep holes have been found to depart by 50%. Until quite recently the methods of surveying deep holes was far from satisfactory and very costly. Two or three ingenious methods have recently been invented, the simplest being by Mr. Wm. Helme, whose instrument records both dip and deviation by means of photographs of a minute plum-bob and compass, which are lowered into he hole to different depths. The photographs are taken by means of two

small electric lamps lit by a "time contact," the electricity being furnished by dry battery. The whole instrument which is only some 30 inches long and 1½ inches in diameter can be lowered in the hole by a wire. This instrument as now made can be operated on steep holes only; but with a few alterations it could be utilized to survey flat holes.

CYANIDE TESTS ON TEMISKAMING ORES.*

By John J. Robertson, Queen's University, Kingston.

In October, 1887, the MacArthur-Forest patent for what has since been known as the Cyanide Process was applied for, and the following year a body of Scottish capitalists, Leonard Gow, and Waverel being the most heavily interested, equipped four expeditions, one to Queensland, one to New Zealand, one to Africa and one to America, to test practically on the field the merits of their patent for the extraction of gold and silver.

From the very beginning the process has been exploited along the broadest scientific lines, a training institution and technical staff being maintained at great expense to investigate every suggestion for improvement, and to train men to successfully cope with the difficulties, which it was foreseen would arise in the treatment of the innumerable combinations of ores likely to be encountered. Had the originators not had implicit faith in their process, or had they approached it in a more cautious manner, it is more than possible that it might still be in its undeveloped condition of fifteen years ago, instead of being the huge and ever growing commercial success it now is.

Of the four initial expeditions, three were failures, and the success of the trial in Africa was largely due to good fortune in stumbling on to an ore especially amenable to cyanide treatment. Its success on the Rand, however, seems to have been assured from the first ; in 1890 the Robinson Tailings Plant was erected and since that time the stockholders in South African Companies owe practically all the dividends they have received to the cyanidation of their tailings. Some idea of the growth of the process may be gained when we consider that in 1889 the total consumption of cyanide in the world was less than 50 tons per annum, while for last year it was fully 10,000 tons, and it

* Student's paper submitted in competition and awarded prize of twenty-five dollars.

has been estimated that half the gold production of to-day is due to this process.

From 1890 to 1900 the process was confined almost exclusively to the extraction of gold from tailings, the extraction of silver being comparatively low, and simply treated as a by-product with the gold. This was, no doubt, due to the fact that gold, while quite as susceptible to the action of cyanide solution, is seldom found in chemical combination with other metals, thus giving less complex reactions, and necessitating fewer modifications of the original process. The difficulties attendant on the successful extraction of silver by the various amalgamating devices in use, and the knowledge constantly forced on metallurgists everywhere, largely through cyanide tests on gold ores, that a certain per cent. of silver could be extracted by the use of cyanide solutions, led to research tending towards the application of the process to ores of silver. These experiments have had more or less success on certain special ores in the western part of the United States, but it is in Mexico that the greatest advance has been made, and within the last few years results here have been so satisfactory as to make the adoption of cyaniding for a large class of silver ores very general.

In 1899 tests were instituted at Guanajuato by the Mexican Gold and Silver Recovery Co. These tests proved unsatisfactory. Later a new series of tests were begun on the same ores, and it was found that by sliming the ore by much finer crushing (the original test was on ore crushed between 30 and 80 mesh), excellent results could be obtained. A slightly stronger solution than is customary with gold was also found beneficial on silver ores, and following these modifications the process in Mexico has been brought to a paying basis.

In Canada, the cyanide process has been in operation for some years on gold ores, but as practically all our silver ores have been galena and blende, comparatively low in silver, the process so far as known has never been tried for silver extraction. The discovery of the new Temiskaming District in Northern Ontario opens up a new field of investigation for the Canadian metallurgist. The ore occurs in very narrow veins, immensely rich in native silver, nickel and cobalt. The vein stuff itself can easily be separated by hand picking, and

is of so high a grade that the expense of smelting would be more than made up for by gaining a slightly higher per cent. of extraction. The country rock in the immediate vicinity of the veins, however, is mineralized to a certain extent, and this runs in value from $12 to $40 per ton in silver. Up to this time this low grade material has been thrown on the dump at the mines, and it is for the treatment of this material, not valuable enough to ship, but too valuable to waste, that a process for treating on the ground must be devised.

During the winter of 1905-1906, shipments of this dump material from three of the mines in the vicinity of Cobalt have been received at the Kingston School of Mines for experimental purposes. We will designate these as Ore No. 30, No. 31, and No. 32.

TESTS ON ORE NO. 30. (A) PAN AMALGAMATION, &C.

Pan amalgamation was first tried. 100 lbs. of the ore was crushed in rolls to 20 mesh, placed in an amalgamating pan and ground to a thick mud. 0.5% copper sulphate and 1% salt was immediately added in solution. After 1½ hours 10 lbs. of mercury was added and grinding continued for six hours. The material was then run into an agitator tank, whence the slimes were drawn off and allowed to settle in tubs. The residue was then panned for concentrates. The tailings and mercury were next removed from the vat and separated into amalgam, concentrates and tailings by panning. The separation of the amalgam from the concentrates was laborious, the final separation being made by drying the concentrates and passing through a 60 mesh screen, leaving the amalgam on the screen. The total mercury recovered was about 80%. The ore originally assayed 87.5 oz. per ton. The products resulting from this test were as follows:—

Products.	Lbs. Recovered.	Oz. Ag. per Ton.	Total Ag. Contents.	Percentage Value of Product.
Concentrates	3.4	1146.5	1.949	44.6
Tails	38.5	29.3	.546	12.5
Slimes	37.2	29.2	.543	12.4
Mercury	8.0	....	.929	21.0
Total	87.1		3.967	90.5

This table shows a loss of 20.9% in weight of ore used, largely lost no doubt in dust in crushing and in slimes in overflow, and accounts in large measure for the 9.5% difference in the total results obtained and the assay value of the ore. The concentrates are of a satisfactory grade and, containing nearly 45% of the values in 3.4% of the weight of original ore, would be an excellent shipping proposition. After a tedious process, however, only 21% of the Ag. value was recovered by amalgamation, leaving 24.9% untouched in the tailings and slimes, or 53.6% after removing the concentrates.

It became quite evident from this test that some better process ought to be tried for the extraction of the values after the separation of the concentrates, and it was for this purpose that cyanide tests were instituted. The first tests were on the tails and slimes of this ore, but without subjecting them to treatment with mercury. Three grades of solution were used of strength. 5% KCy., 25% KCy. and 15% KCy.

Samples, each weighing 2 A.T., were placed in bottles and 100 grams KCy solution added, one set of bottles allowed to stand 14 days, and a duplicate set tied to a slowly revolving wheel so that the bottles turned over endwise, and they were thus agitated for 72 hours. After the treatment was completed the material was filtered, washed, and the mud assayed with the following results.

TESTS ON ORE NO. 30. (B) CYANIDING WITH AGITATION.

Strength Sol. Used.	Assay Val. Before Treatment.	Assay Val. After Treatment.	% Extraction	Consumption of KCy in lbs. per ton of ore.
.5%	9.88	5.16	47.8	2.7
.25%	9.88	3.00	69.5	1.6
.15%	9.88	4.24	57.1	.9
		SLIMES.		
.5% Sol.	30.7	8.46	72.5	5.1
.25% Sol.	30.7	6.8	77.9	3.3
15% Sol.	30.7	14.76	52.0	2.4

TESTS ON ORE NO. 30. (C) CYANIDING WITH LEACHING.

TAILS.

Strength Sol. Used.	Assay Val. Before Treatment.	Assay Val. After Treatment.	% Extraction.
.5% Sol.	9.88	6.02	39.1
.25% Sol.	9.88	3.68	62.8
.15% Sol.	9.88	4.86	51.8

SLIMES.

.5% Sol.	30.7	10.82	64.8
.25% Sol.	30.7	15.10	50.8
.15% Sol.	30.7	18.08	42.1

The consumption tests in above table were taken after treatment was complete, and are much higher than we would expect to find in actual practice.

These results demonstrate first, that the tailings from this ore are amenable to cyanide treatment, second, that the cyanide consumption is not excessive, third, that agitation will give a higher extraction value than leaching, fourth, that the slimes in the more finely crushed product yield a higher per cent. of value than the coarser material.

TESTS ON ORES NOS. 31 AND 32.

At the same time similar tests were run on ore No. 31, which, however, was cyanided direct without concentration as it was of a much lower grade, assaying about 24.5 oz. of silver per ton.

Ore No. 32 was crushed in a stamp mill instead of rolls, and then run over a Wilfley Table where 71.9% of the silver values were recovered in the concentrates and middlings. The tailings and slimes were treated by cyanide with agitation. Various strengths of cyanide solution and various times for agitation were tried. In each case the largest percentage of extraction was obtained from the slimes and the least from the coarsest tailings.

CONCLUSIONS.

While these results are incomplete and only of a preliminary nature, we are justified in the following conclusions. First, that it will be possible to treat the ores tested after the removal of the concentrates, at an excellent profit, by the use of the cyanide solutions; second, that such a treatment will save a higher percentage of the values and be more suitable to the ore than by the use of amalgamation.

Practically all the details of the process are yet to be worked out. The results would indicate that a much better extraction can be obtained by finer crushing, but how fine it is economical to crush the ore is yet to be determined by experiment. The strength of the solutions most economical to use is yet to be determined. No tests for acidity have been made, and it is probable that the consumption of cyanide can be greatly reduced. No attempt has been made to precipitate the silver from solution, but difficulties from the fouling of the solutions interfering with the deposition of the silver are not to be expected from these ores.

NUMBER FOUR PIT—BRAYTON DOMAIN COLLIERIES, CUMBERLAND, ENGLAND.*

By R. P. Cowen, McGill University, Montreal.

The Brayton Domain is situated in the eastern section of the Cumberland coalfields. Number Four pit has been worked for 13 years; the three former pits being worked out. A great deal of the plant of Number Four was previously in use at Number Three Pit. The present output is about 750 tons per day.

In this part of the coalfield there are four seams, only one of which is worked, namely: the "Yard Band." This seam varies in thickness from 4 ft. 6 in. to 5 ft. with an average of 4 ft. 10 in., and is 546 ft. below the surface at the shaft. The general dip of the "Yard Band" is 8 ft. in 100 ft. and the strike is N.N.W. There are 24 faults in the area worked by Number Four pit, the largest having a throw of 18 ft.

The coal is good, clean, bituminous, except a band of blackstone from 2½ in. to 3 in. thick about 10 in. from the bottom of the seam.

The underlying rock is black shale, but in many places the seam is separated from this by a bed of white clay. The roof is black shale in some places and freestone in others. The mine is worked on the pillar and room system, the pillars being 60 ft. thick. The cars follow clear up to the breast. Two miners work at each face and each fills his own car. The coal is undercut either by hand or by a "Champion" channelling machine of which there are two at work giving good satisfaction. They work with compressed air at 40 lbs. pressure and give 300 blows per minute. The undercut is three feet deep. Holes are drilled by hand near the top of the seam and fired in pairs. For the hand cutting each miner is allowed four picks per day. The picks are almost straight and weigh 2¼ lbs. each. The shovels, hammers, wedges and clay tamping are also supplied by the company. The miners find their own drills.

* Student's Paper submitted in competition and awarded prize of $25.

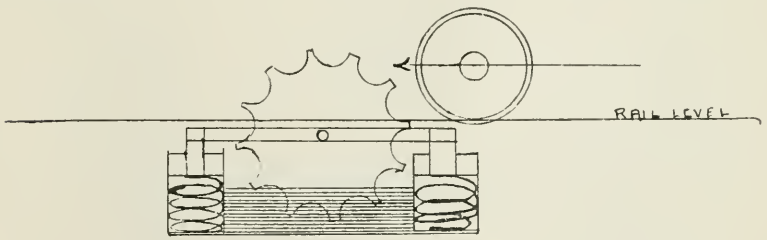
The holes are 1 in. diameter and 3 ft. 6 in. deep. They are charged with compressed powder or gelignite and tamped with clay. The powder is fired by squibs, and the gelignite by electricity. The mine is divided into five districts for the purpose of blasting, and one man fires all the holes in each district.

The cars are taken from the breasts to the nearest main haulage way by boys and ponies and are left there to be called for by the main haulage trammers. The main haulage ways are 10 ft. wide by 6 ft. high, some are double tracked and some single. Where the grade is not too great the hauling is done by ponies, but there are 16 places of varying length where the grade is too steep for ponies. The cars are hauled up these by compressed air winches. This hauling is done in trips of 20 cars, except on one grade, which is especially steep, where trips of only 12 are taken.

The cars are square and hold 9 cwt. of coal. They are built of wood and weigh 5 cwt. There are no brakes on the cars, all the braking being done with sprags.

At present a new endless rope haulage is being installed to do away with three short ones. It will be 3,000 ft. long. The power will be supplied by a 40 h.p. steam engine on the surface and the rope will pass down the main shaft. The rope will be $\frac{7}{8}$ in. diameter and travel at $1\frac{1}{2}$ miles per hour. It will take 200 tons per 8 hour shift. The cars will be made up into trains with a clutch bogie at each end. The rope will run on the ground between the rails, and the bogies will have screw clutches.

On each haulage way there is an automatic greasing apparatus.



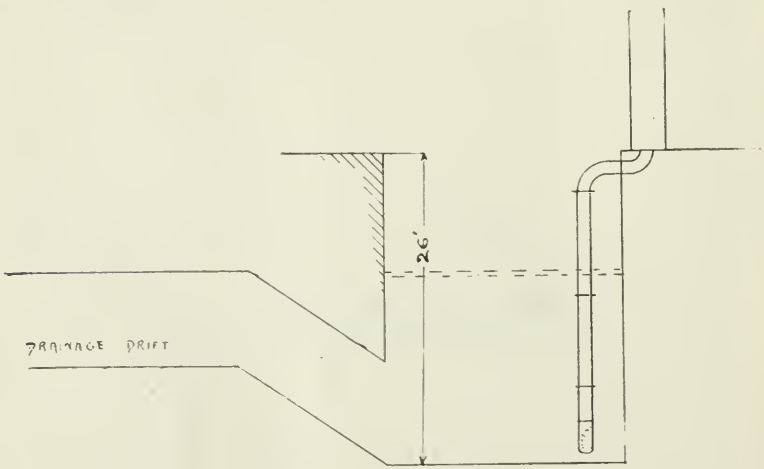
A wheel on each side of the track is supported on springs. There are grooves in the circumference which engage with the axles of the cars. The bottom of the wheel dips in a grease box.

The axles turn the wheels as they pass and are greased, each axle catching a fresh groove.

Timbering—The roof being a very good one, not much timbering is needed. In some of the faults, the main gangways are bricked. Where timbering is needed in the main ways, steel girders are used resting on 5 ft. props. The props are set at varying distances apart according to the state of the roof. The props are bought ready cut to 5 ft. lengths and are 4 in. to 5 in. diameter.

Lighting.—The lamps used are the "Protector". They are plugged by lead plugs and ignited by electricity. When the lamp is opened, the flame has to pass through a tube and so is extinguished. The gas is tested for with the ordinary Davy lamp. The lighting near the bottom of the main shaft is done by electricity and acetylene. The acetylene plant is in a room near the bottom of the shaft and will supply 25 lights. It is used altogether when the electric light is being used on the surface, but during the day both are used.

Drainage.—There are 15 Tangys compressed air pumps in various parts of the mine varying from 8 in. to 5 in. water barrel, All these pump into a drift which leads to the sump at the bottom of the upcast shaft. The drift is arranged so that if the pump were stopped beyond a certain time the water would overflow

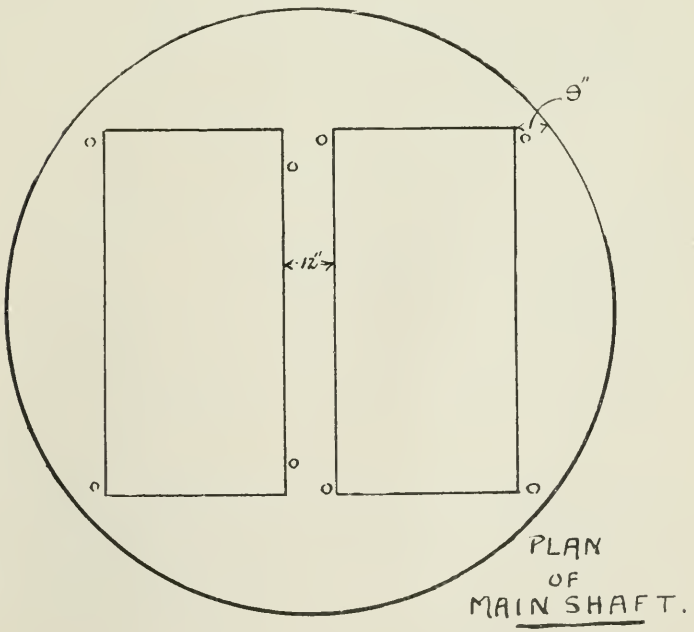


into the old workings. These are of such capacity that the pump can be stopped for a week without overflow.

The water is pumped from the sump to the surface by a double ram Cornish pump. The pump engine has two cylinders in tandem, the high pressure cylinder being 30 in. diam. and the low pressure cylinder 50 in. diameter with an 8 ft. stroke.

The pump has a capacity of 100 gals. per minute and works usually for 5 hours a day. There are two rams, the lower one of 18 in. diam. brings the water to half way and empties it into a tank from which the upper ram of 20 in. diam. brings it to the surface.

The main shaft is 13 ft. diameter and 546 ft. deep. It is circular and lined with brick all the way down. There are two cages which run on guide ropes. The guide ropes are $1\frac{1}{8}$ in. diam., and are hung from the head frame. On the bottom they have weights of 18 cwt. each.



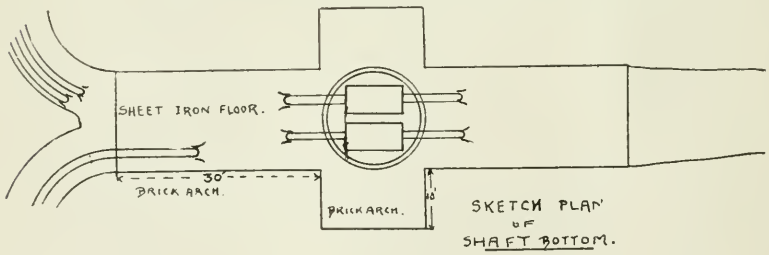
The cable is compound plough steel 1⅛ in. diam. and 6 strand 6 coil. It is renewed every two years. The cost of hoisting with regard to the cable is 1 penny for every 27.5 tons of coal hoisted. The cages run balanced, and there is also a balance rope of the same dimensions of the hoisting rope.

The hoisting engine is of 100 nominal horse-power, the steam cylinders being 24 in. by 48 in. The connecting rods act directly on the drum which is 12 ft. diam. The brake is applied by foot, and the engine is reversed by hand. The signals are given by electric bells, and the engineer can see the top of the shaft from his seat. An indicator is worked by a worm on the drum axle. The rate of hoisting is 1,200 ft. per minute, and 500 tons of coal are hoisted per 8 hour shift. There is no safety device on the cages.

The cages are built of milled steel, and weigh 1½ in. each. They are double decked, and each deck takes two cars.

The brick lining of the shaft rests upon four arches of brick. These arches extend for 30 ft. back from the shaft on the two haulage ways and 10 ft. back at right angles to these.

The floor in the neighbourhood of the shaft is covered with sheet iron and the cars are run and turned on this. The ends of the tracks are tapered, and there are two guide rails which lead the cars onto the tracks.



The upcast shaft is seventy feet from the main shaft. It is 10 ft. diam. and brick lined. The pump rods and compressed air pipe pass down it. A single cage runs in the shaft for the purpose of examining the pump, rods, etc. For the upper 40 ft. of the shaft, the air is boxed into a separate compartment and leaves the shaft up an incline to the fan.

The coal produced is of two qualities A and B. A is fairly clean coal, the B coal comes from below the parting and is much dirtier.

The coal is fed onto screens, shaking at the rate of 118 per minute. The first screen is $1\frac{1}{4}$ in. mesh and the second is 1 in. mesh.

The big coal goes over onto the picking belt. The belt is of sheet iron plates 4 feet wide, and travels at 45 ft. per min The part where the picking is done is 30 ft. long. Nine pickers, most of them girls, stand on each side. From the belt the coal goes over a screen to take out the fine that has been produced in the picking, and thence down a shute into the cars.

The screens, picking belts, and dumping apparatus are worked by a steam engine 30 in. by 15 in. cylinder, running at 118 revs. per minute.

There are two coal washery houses, one for the "country," or coal to be sold, the other for the coke ovens. All the coal may be turned into either houses if desired.

When washing for coke, coal through the 1 in. screens drops into a conveyor, which takes it to the coke wash house, where it is elevated by a bucket conveyor into three jigs running 60 strokes per minute. The screens are of 1-16 inch wire screen. The slate collecting on the bed is cleared off intermittently from the end.

The washed coal from these jigs goes over a $\frac{3}{4}$ inch screen which separates the nut. The coal through this screen drops onto a travelling belt conveyor, 48 ft. long and 15 in. wide, running at 350 ft. per minute. It will take 100 tons per eight hour shift.

The conveyor drops the coal into a Carr revolving crusher which breaks it very fine.

The crusher works at 400 revs. per minute. It is driven by a steam engine, 14 in. by 18 in. cylinder, working at 120 revs. per min. and belted to a counter shaft, working at 240 revs. per min. and thence to the crusher.

The coal from the crusher drops into an iron car holding 30 cwt. The car when full is taken up by an hydraulic elevator to the level of the top of the coke ovens and is run off onto the tracks over the ovens.

When washing for the "country," the coal through the $1\frac{1}{4}$ in. screen drops into a conveyor and goes straight to the cars as

"unwashed nuts". If desired, it can be taken to the wash house instead, in which case it comes out as best "washed nuts." The coal through the 1 in. screen goes into a worm conveyor and is taken to the country wash house, where it is elevated by a bucket conveyor into a revolving trommel with $\frac{3}{8}$ in. and 1-10 in. mesh.

Coal over the $\frac{3}{8}$ in. goes into jigs similar to those already described, but with a stroke only two-thirds as long, at 70 per min. The slate on the bed is cleared intermittently from the end.

The heads from these jigs go into a tank and mix with the "washed nut."

Coal through the $\frac{3}{8}$ in. screen is jigged also on a short stroke jig at 100 per min. This jig has a bed of broken tile. The heads from these jigs are called "washed pea."

Coal below 1-10 in. goes into a Duff revolving rifled tube washer. The heads from here flow out onto a shaking screen to partly dry them, and are then burned in the Lancashire boilers of the company's own plant as they are too fine to sell.

There are 82 beehive coke ovens, each 11 ft. diam. inside, built in a double row with two Babcock and Wilcox boilers in the middle. Tracks are laid over each line of ovens, and the car of crushed coal is run over an oven and dumped in through the top of the oven. The charge for each oven is 5 tons of crushed coal, and the product is $2\frac{3}{4}$ tons of coke. The coke is pulled out of the front of the ovens, and quenched outside. The charge remains in for two days. The following is an analysis of the coke produced.

Volotile matter	0.80
Carbon	90.62
Ash	6.88
Sulphur	1.30
Moisture	0.39
	99.99

Steam Plant.—Until two years previous to the writer's visit, steam had been supplied by 8 Lancashire boilers working at 70 lbs. and hand fired with the small coal from the Duff washer mixed with pea coal.

Two Babcock and Wilcox boilers were put in at the coke

ovens and heated by the gases from the ovens. These boilers work at 120 lbs., and the steam is mixed with that from the Lancashire boilers, thus enabling the latter to be worked at a much lower pressure, and it is found that they can burn the slime from the settling tanks. The greater part of the fine coal from the Duff washer, which was formerly burned in the boilers, now goes to the coke ovens, and no pea is burned at all. This installation has resulted in a saving of over £1,000 per annum.

Shops.—The machine shop contains one large and one small lathe, a planer and a drill press. All are driven by a separate steam engine which also drives a Sirocco fan which supplies the blast for the smithy.

The saw mill is run by another small steam engine, and contains two circular saw benches and a band saw.

The smithy has eight fires, a power hammer and a punch. The drills are hand sharpened, at the rate of 120 per 16 hour day.

The cages and trams are all built in the shops.

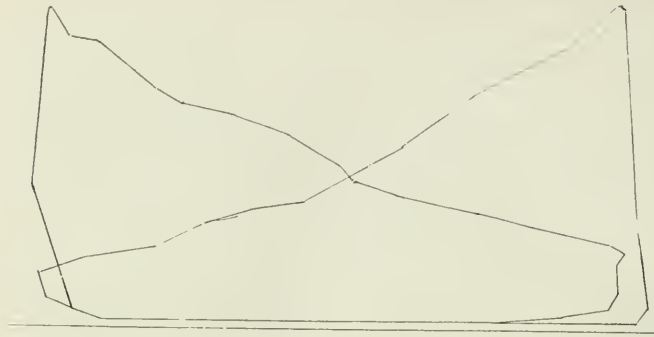
Compressor.—The compressor is by Walker, of Wigan, and is a single stage duplex. The steam cylinders are 30. in by 60 in. and the air cylinders 29¼ in. by 60 in. It is worked with a ⅝ cut off at 40 revs. per minute. The air is compressed to 65 lbs. per square inch, and goes from the compressor into three receivers each 3 ft. 6 in. by 30 ft. From these it goes through a 9 in. pipe down the upcast shaft. Near each pump or winch underground there is a small receiver made from a Lancashire boiler tube with ends added.

In the same room with the compressor is a 20 h.p. vertical steam engine working at 250 revs. and driving, by a belt, a dynamo which supplies electric light for the surface and for 25 lights underground at 110 volts.

Fan.—The ventilating fan is an 18 ft. diam. Waddle type, and has a capacity of 50,000 cubic feet. per min. at 120 revs.

The fan engine has a single cylinder 14 in. by 17 in. and is direct connected to the fan.

While the writer was at the mine an indicator diagram was taken from the fan engine, with the following results:



H.P. in air

48,720 × 2.15 W.G. × 5.2.

H.P. in Air.

$$\frac{48{,}720 \times 2.15 \text{ W.G.} \times 5.2.}{33{,}000} = 16.6$$

H.P. of Engine.

$$17.27 \times \tfrac{3}{2}\ 2 \times \frac{153.938 \times 115}{33{,}000} = 27.79$$

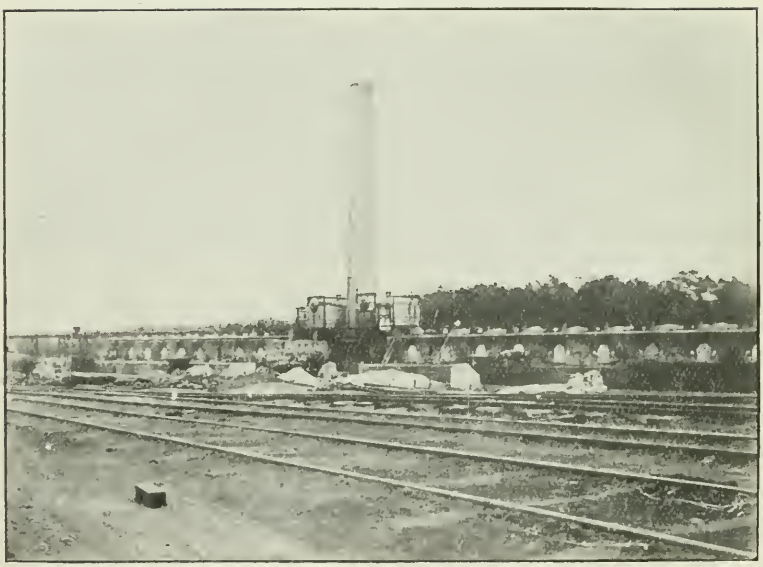
$\therefore$ Efficiency = 59%.

Surveying.—The company employs a surveyor and two apprentices. The surveying is done with compass and chain. The compasses have clinometer attachments. The stations are marked by plugs in the roof.

The miners are paid by the ton in the breasts, and by the yard in narrow work or rock. The cars are ticketed by the miner and the runner, who is paid by the car also. The cars are all weighed at the top of the shaft. A tare of 5 cwt. is reckoned for each car. The tally also shews whether the coal is from the top or bottom of the seam. The two qualities are picked on separate belts but are paid for at the same rate.

General View, Headworks, No. 4 Pit, Brayton Colliery.

Another View, showing Railroad Track.



The Coke Ovens.

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